Willard Spur Nutrient Cycling

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Research Team Update
Science Panel Meeting
January 28, 2013

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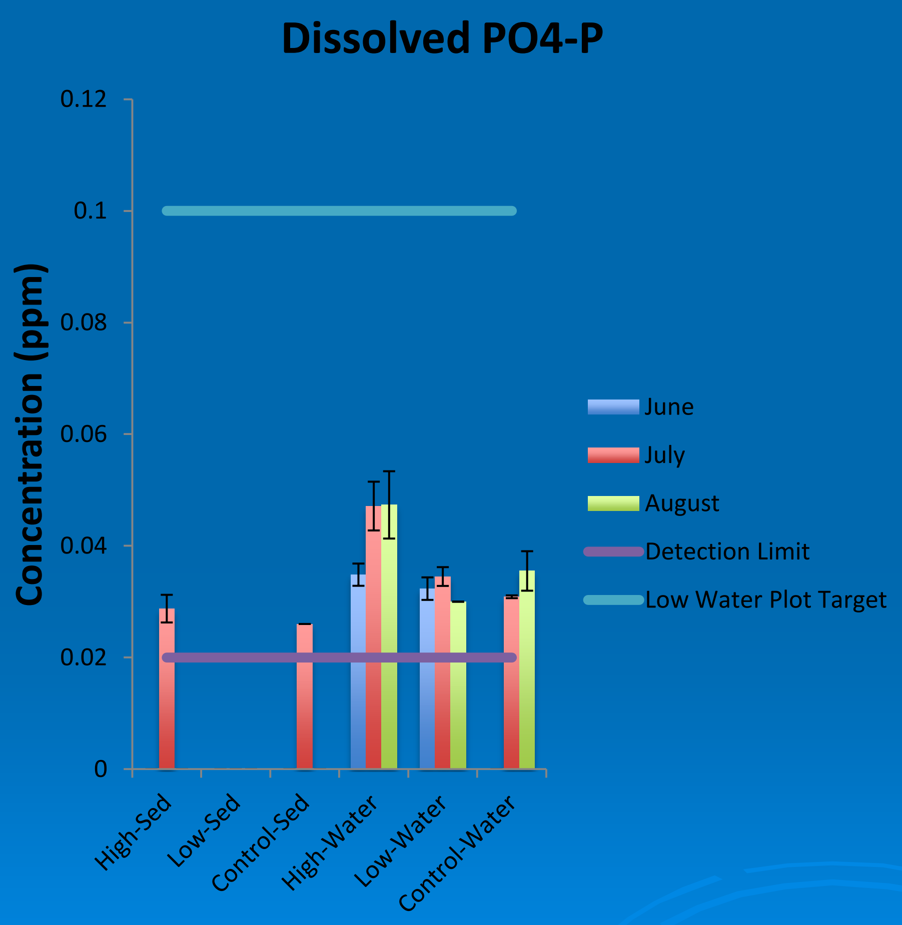
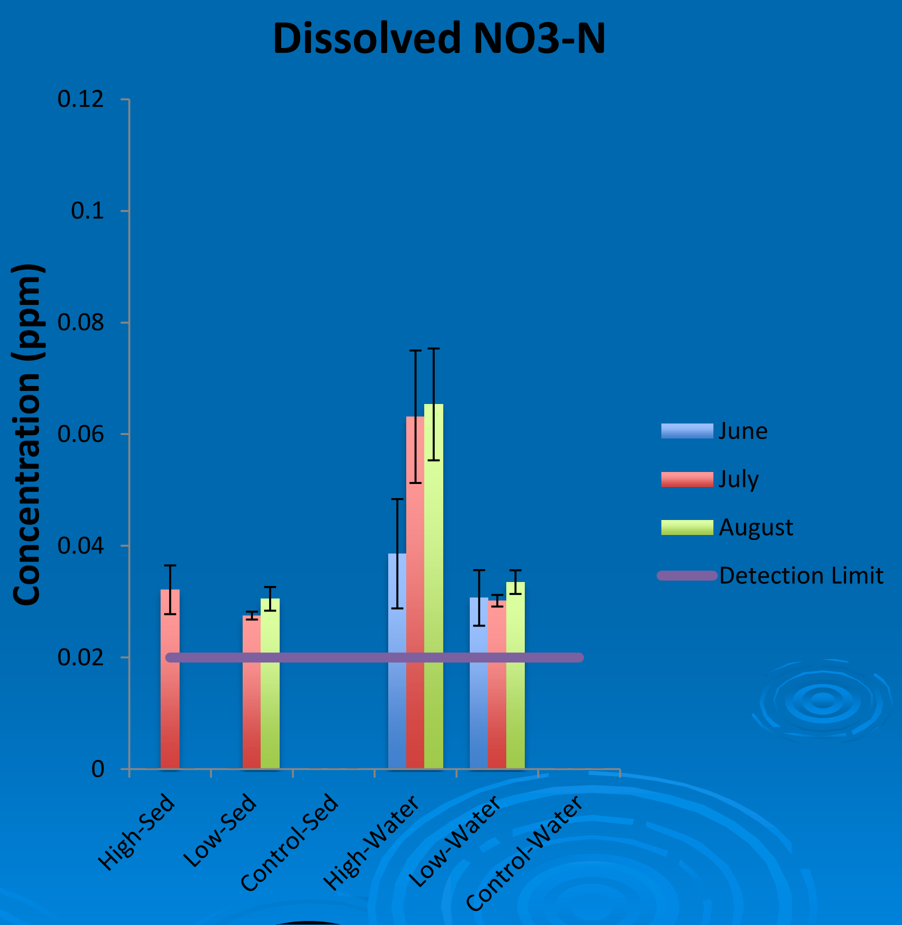
Water and Sediment Chemistry

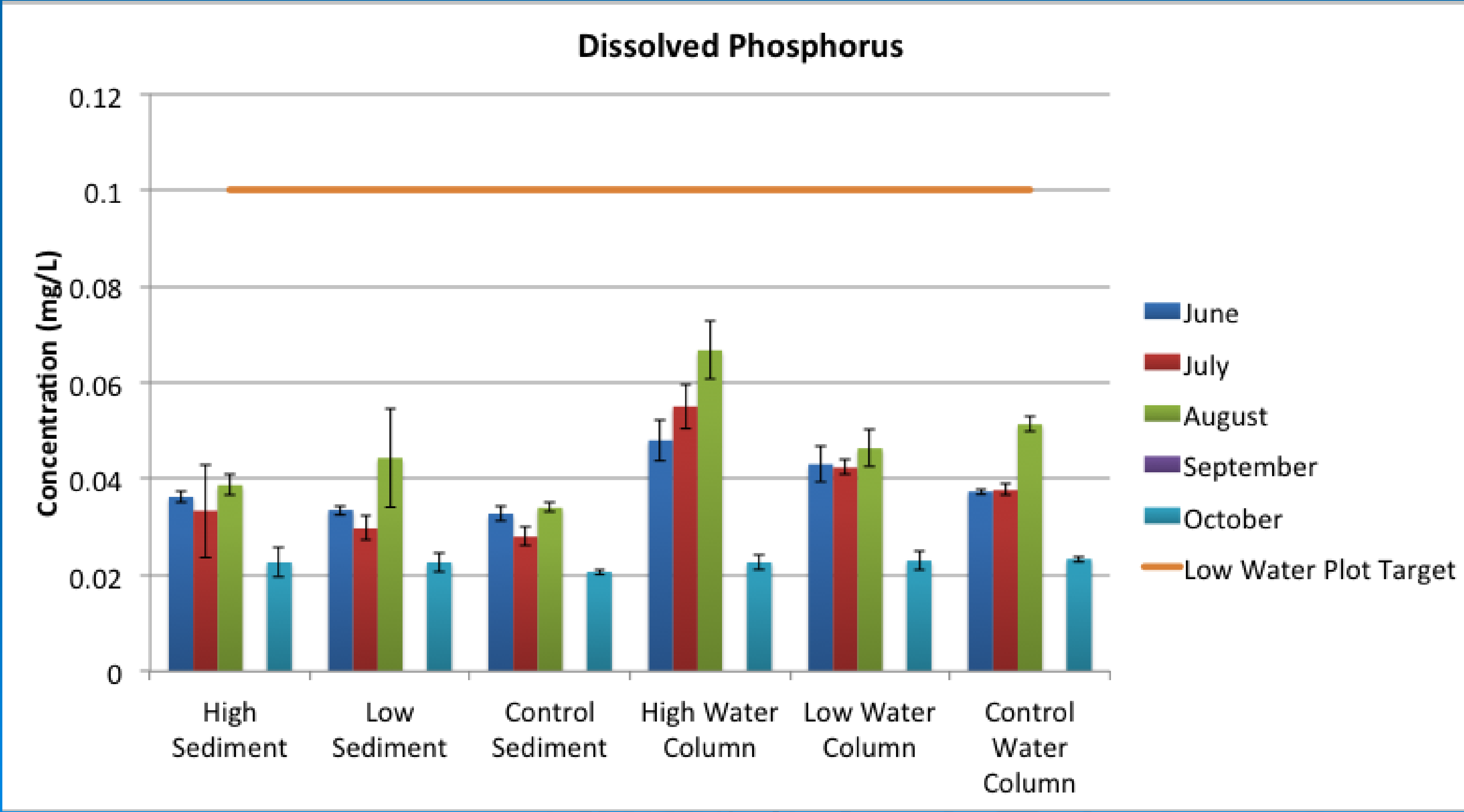
Results

Water Column Nutrients: Dissolved Phosphate and Nitrate

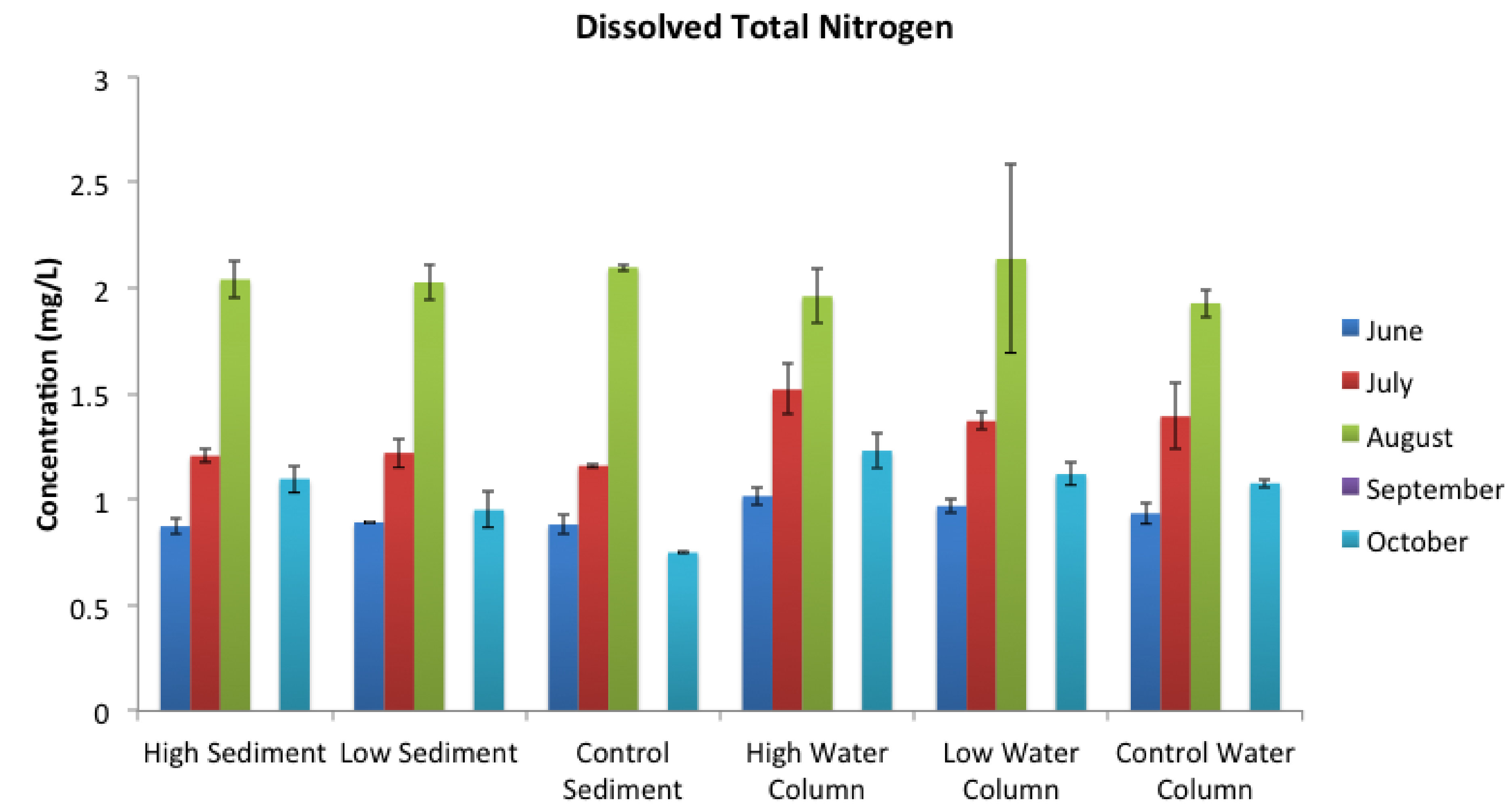




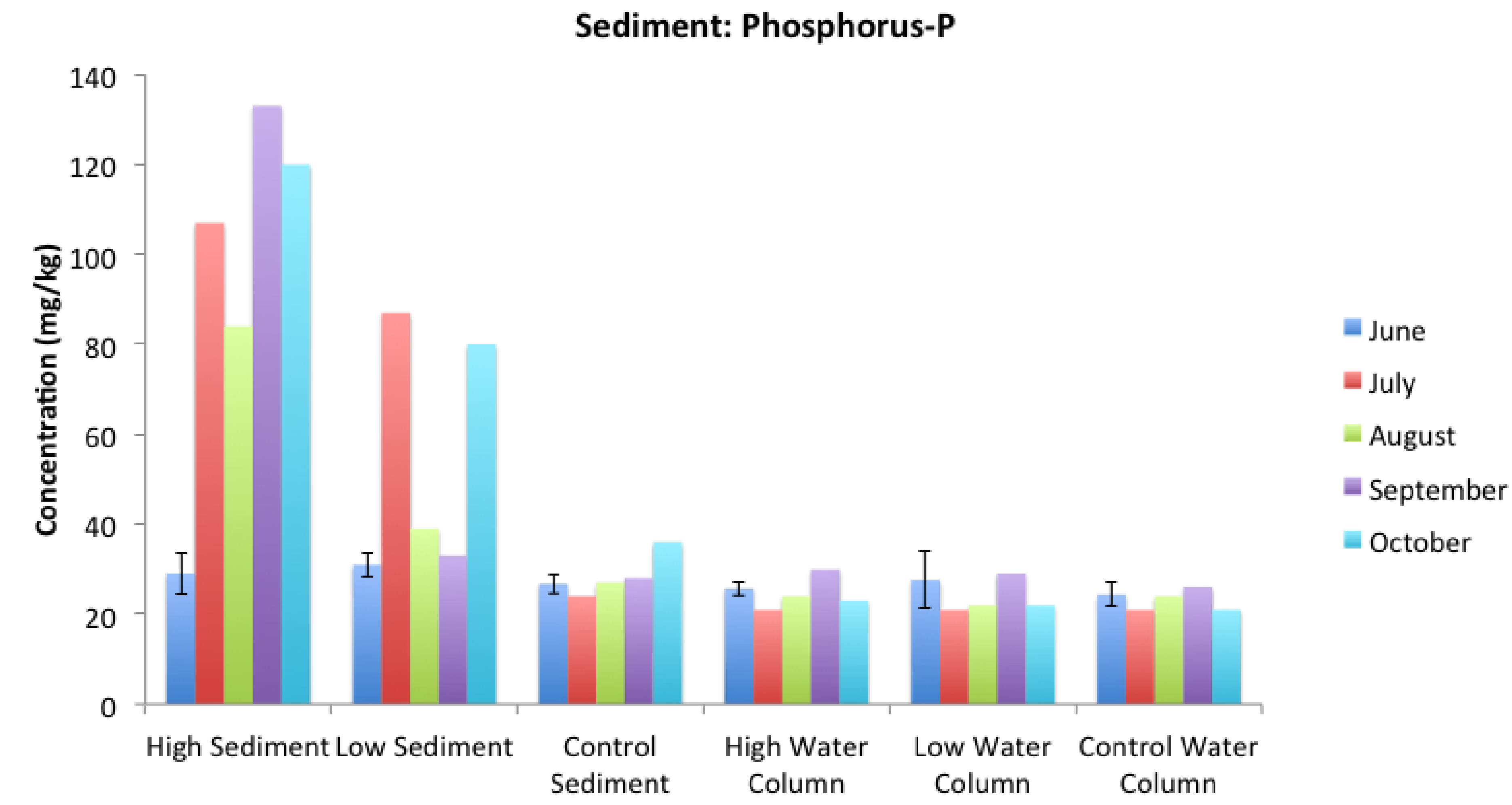
Water Column Nutrients: Dissolved Phosphorus



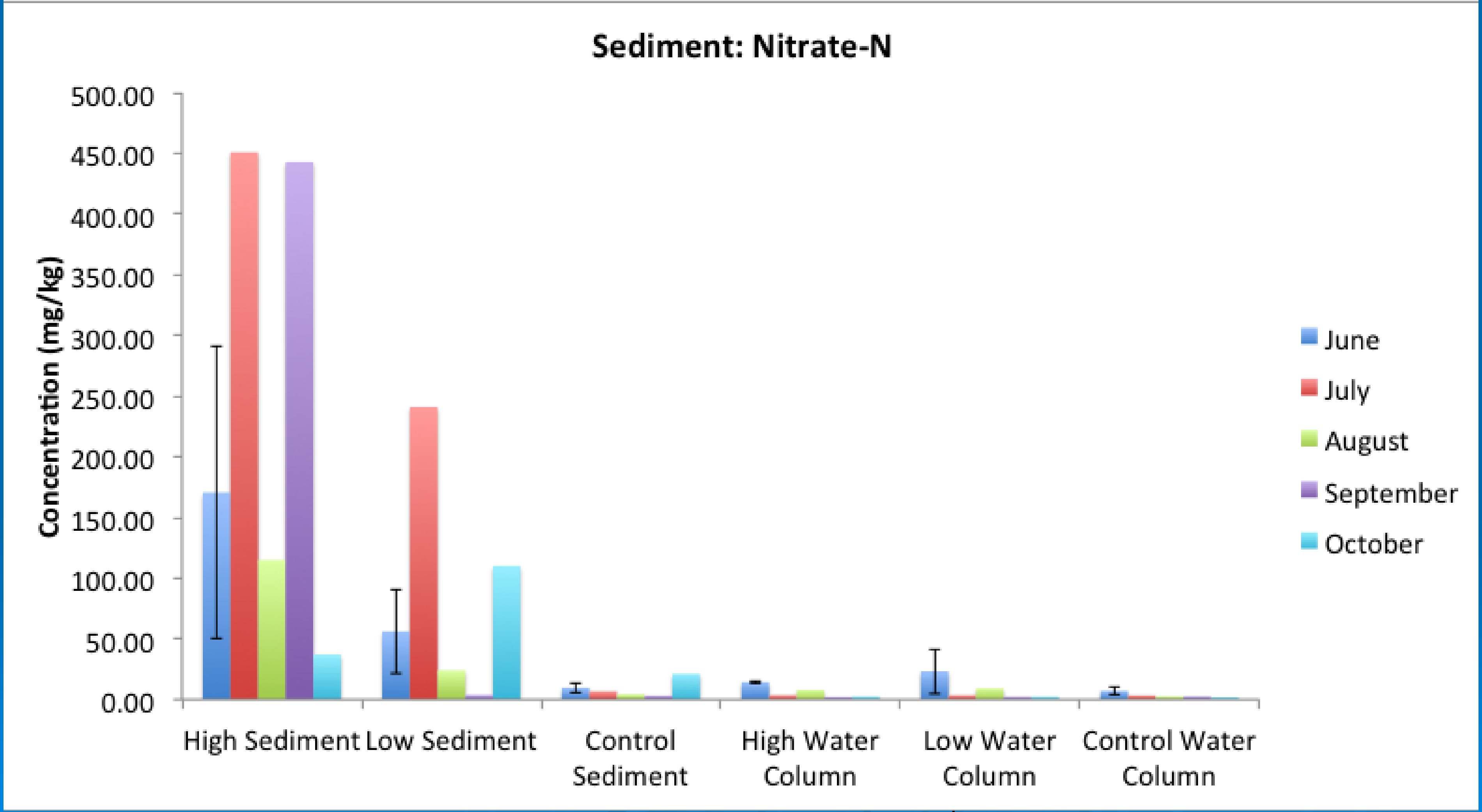
Water Column Nutrients: Total Nitrogen



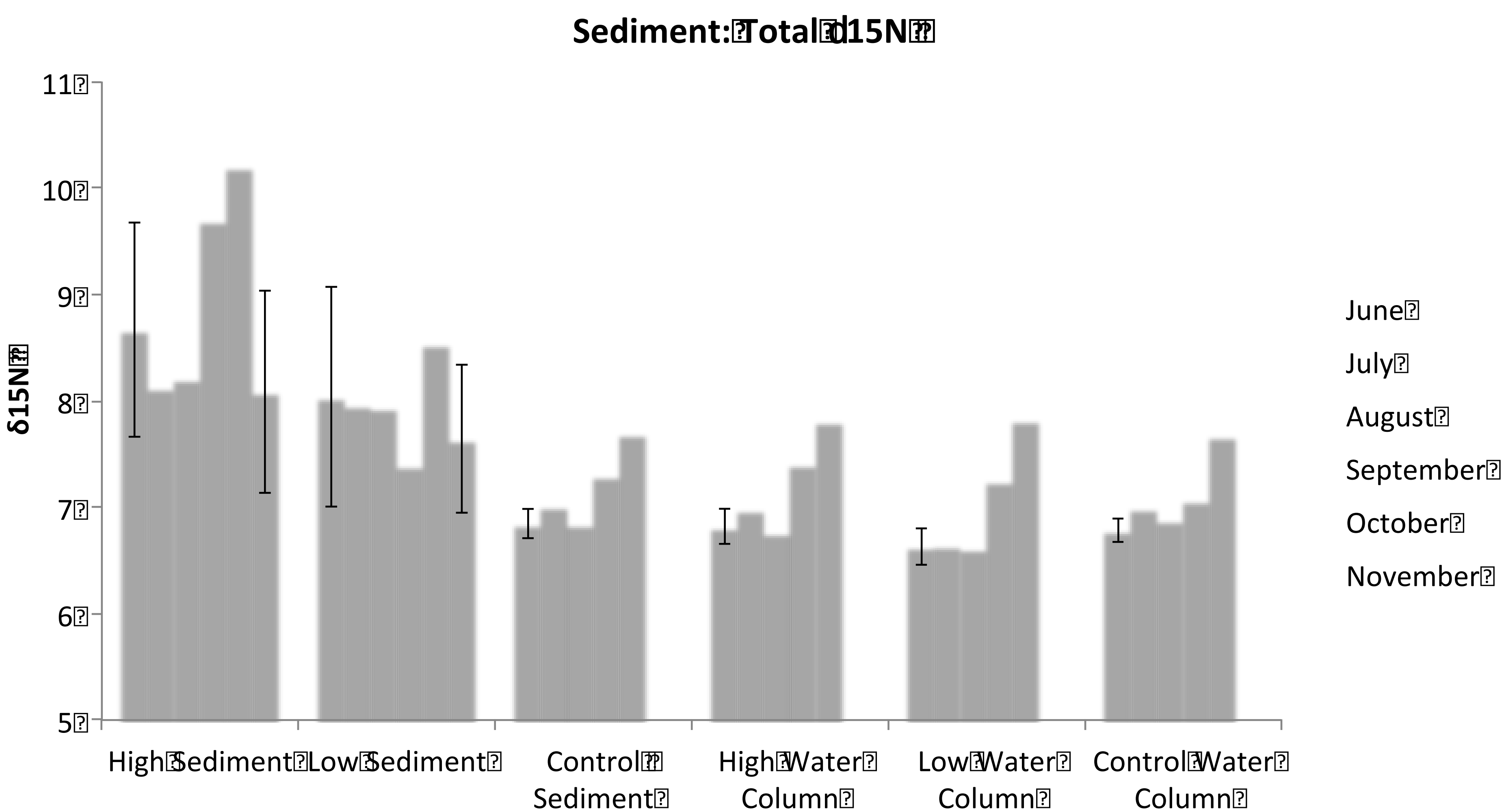
Sediment Nutrients: Phosphorus



Sediment Nutrients: Nitrate



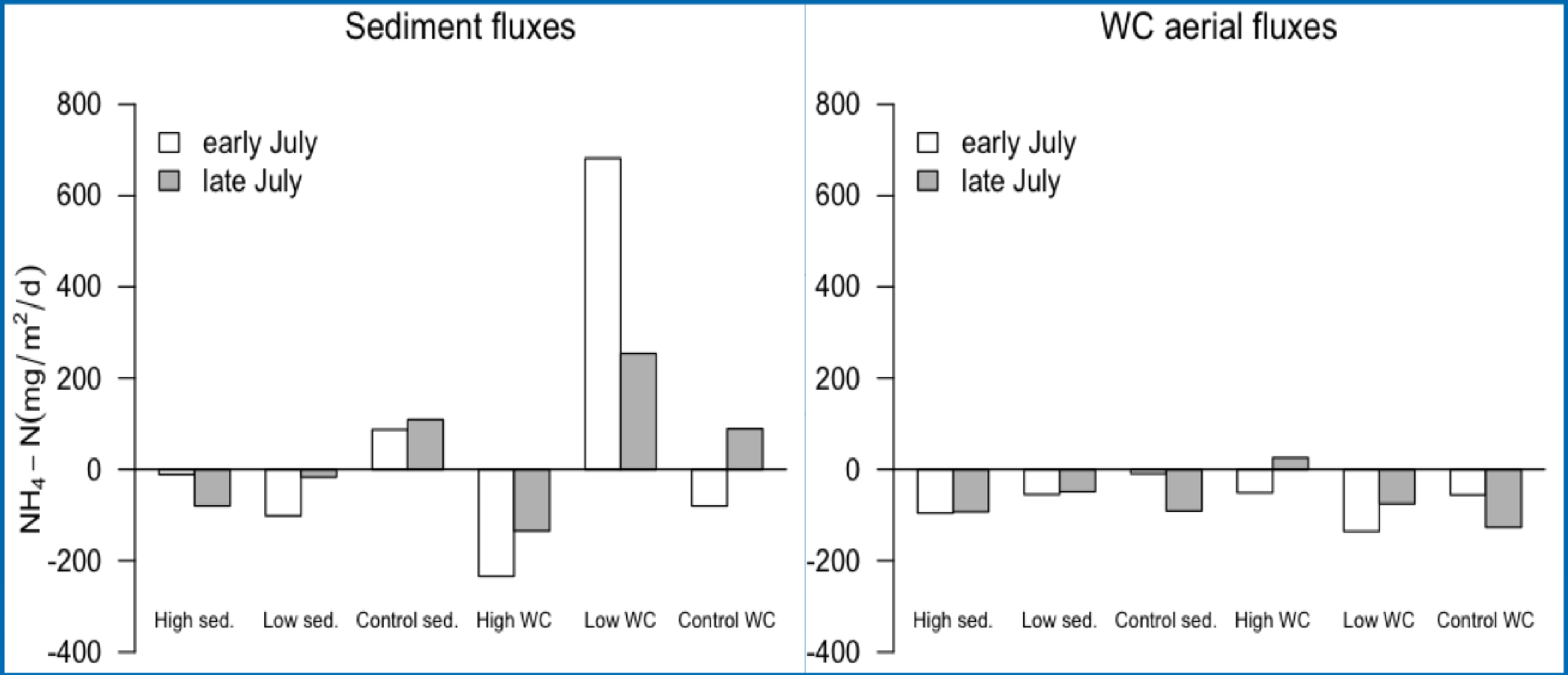
Sediment $\delta^{15}N$ Isotope Values



Daytime Nutrient Dynamics / Flux

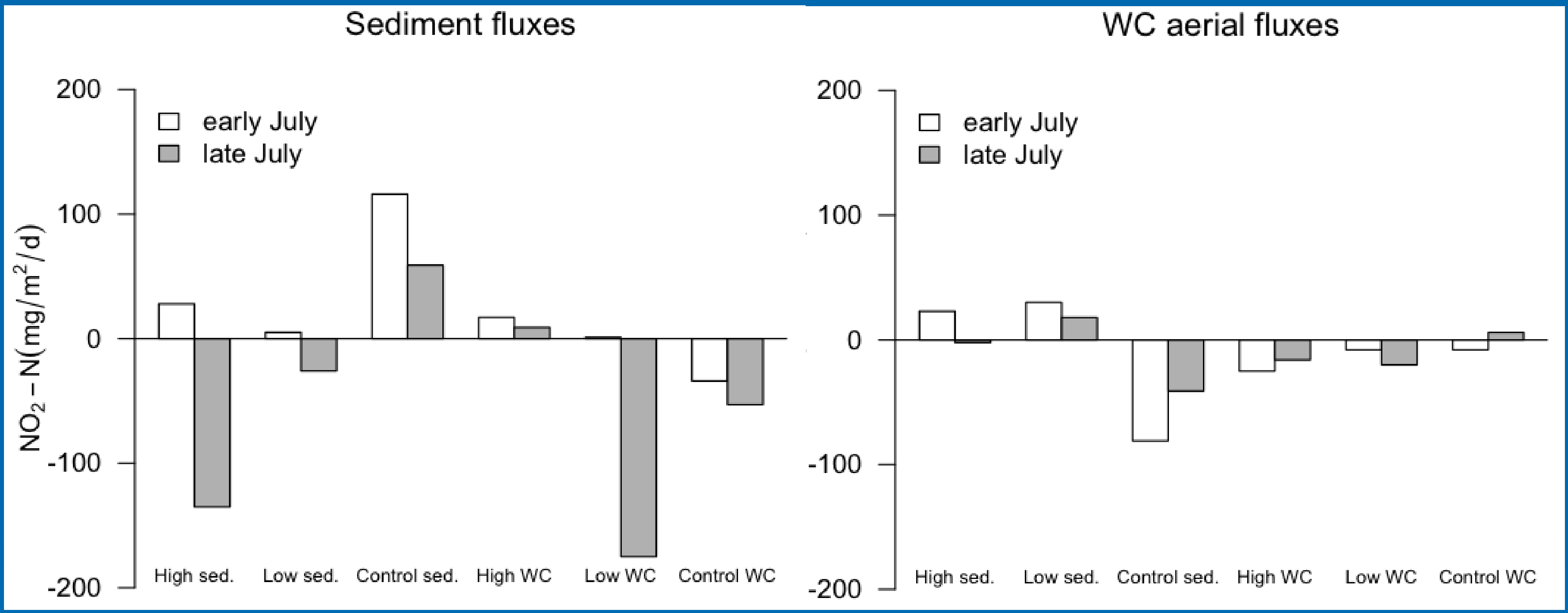
Results

Sediment and WC fluxes- Ammonia



- Sediments removed ammonia from the WC during daylight hours
  - exceptions (Control Sediment & Low Water Column)
- WC removed ammonia during the daylight hours

Sediment and WC fluxes- Nitrite



Estimated Ambient Nutrient Dynamics

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		Estimated daytime ambient nutrient dynamics (mg/L/day)				
Plot	Date	NH_4-N	NO_2-N	NO_3-N	TIN	PO_4-P
High Sediment	7/12/12	-0.228	0.109	-0.096	-0.215	-0.096
High Sediment	7/26/12	-0.412	-0.326	-0.112	-0.85	-0.017
Low Sediment	7/12/12	-0.334	0.074	-	-0.26	-
Low Sediment	7/26/12	-0.157	-0.019	-0.055	-0.231	-
Control Sediment	7/12/12	0.166	0.074	-	0.24	-
Control Sediment	7/26/12	0.043	0.043	-	0.086	-
High Water Column	7/8/12	-0.594	-0.017	-	-0.61	-
High Water Column	7/31/12	-0.266	-0.017	-0.18	-0.463	-0.117
Low Water Column	7/8/12	1.138	-0.015	0.221	1.344	-
Low Water Column	7/31/12	0.437	-0.476	0.134	0.095	0.139
Control Water Column	7/8/12	-0.283	-0.088	-	-0.371	-
Control Water Column	7/31/12	-0.093	-0.095	-	-0.188	-0.063

1. measured ambient nutrient concentrations will not maintain daytime N and P consumption rates
2. Primary Production in the benthos and water column consuming nutrients faster than sediment release
   - need to measure nighttime nutrient dynamics to determine nutrient load associated with sediments

Traditional Nitrogen Removal in Wetlands

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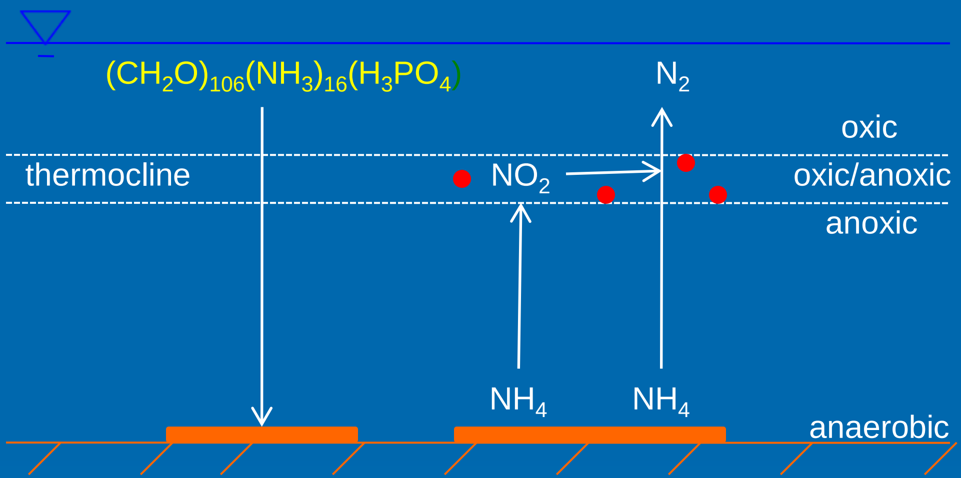
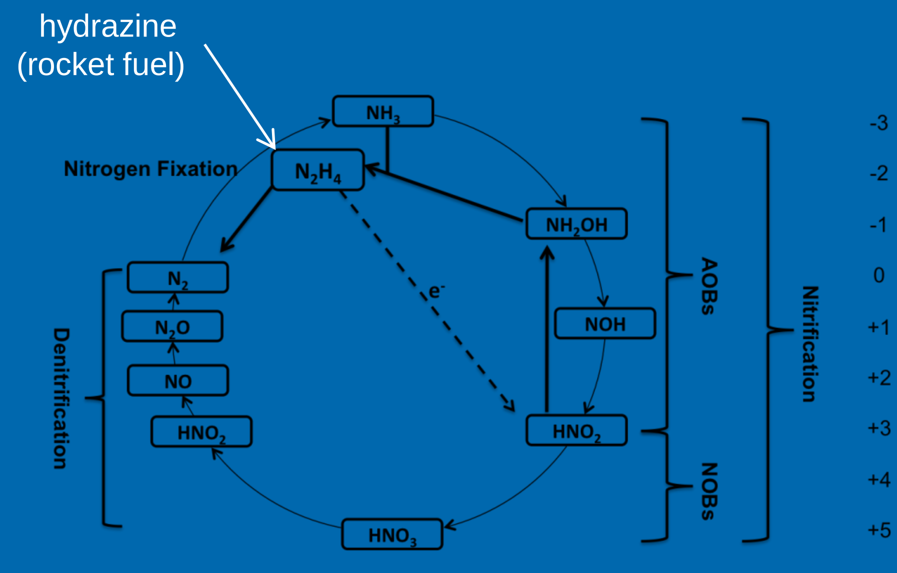
- Oceanographers noticed ammonium deficits in anoxic waters (Richards 1965)
  - postulated using thermodynamics with molar ratios of NO_2:NH_4 of 1:1 and 1.67:1 (Broda 1977)
  - 50-70% of N_2 gas produced in ocean
    - 30% of every breath we take





[adapted from Ahn, 2006]

- Ammonia Oxidizing Bacteria (AOBs)

$55NH_4^+ + 76O_2 + 109HCO_3^- \Rightarrow C_5H_7O_2N + 54NO_2^- + 57H_2O + 104H_2CO_3$

- Nitrite Oxidizing Bacteria (NOBs)

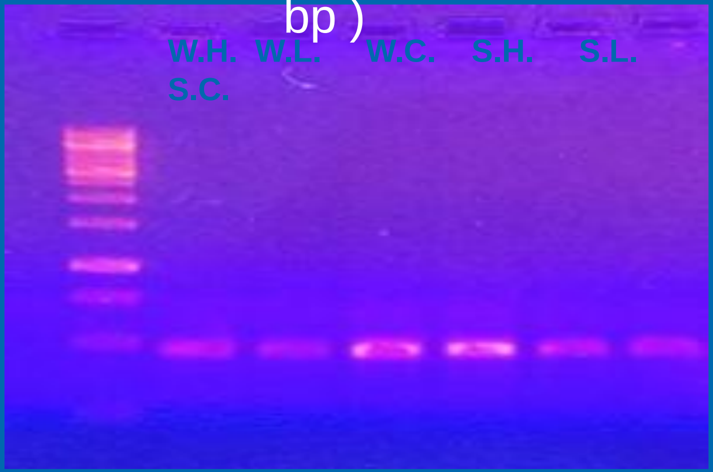
$400NO_2^- + NH_4^+ + 4H_2CO_3 + HCO_3^- + 195O_2 \Rightarrow C_5H_7O_2N + 3H_2O + 400NO_3^-$

- Anammox (anaerobic ammonium oxidation)

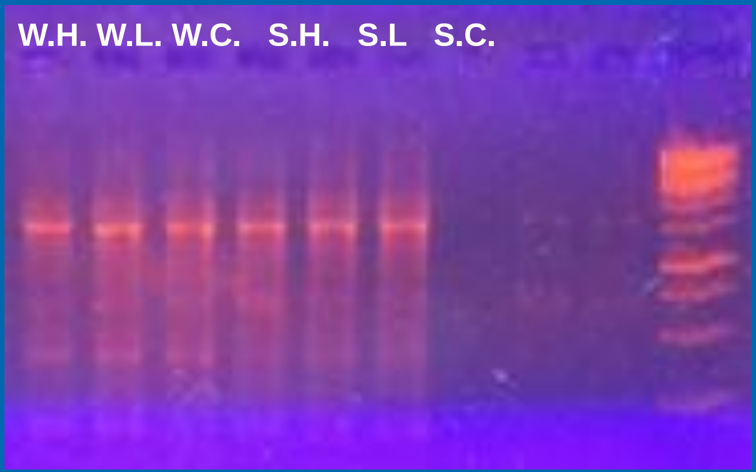
$NH_4^+ + 1.32\ NO_2^- + 0.066\ HCO_3^- + 0.13\ H^+ \rightarrow 1.02\ N_2 + 0.26\ NO_3^- + 0.066\ CH_2O_{0.5}N_{0.15} + 2.03\ H_2O$

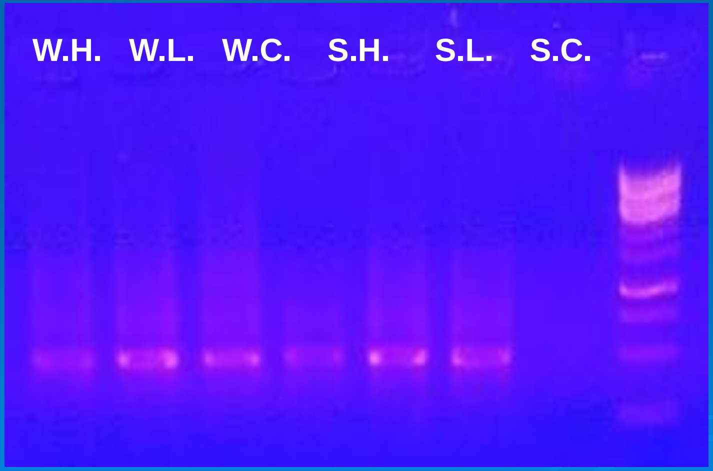
Molecular Tests

AOBs (amoA gene) PCR (fragment size of **491** bp)

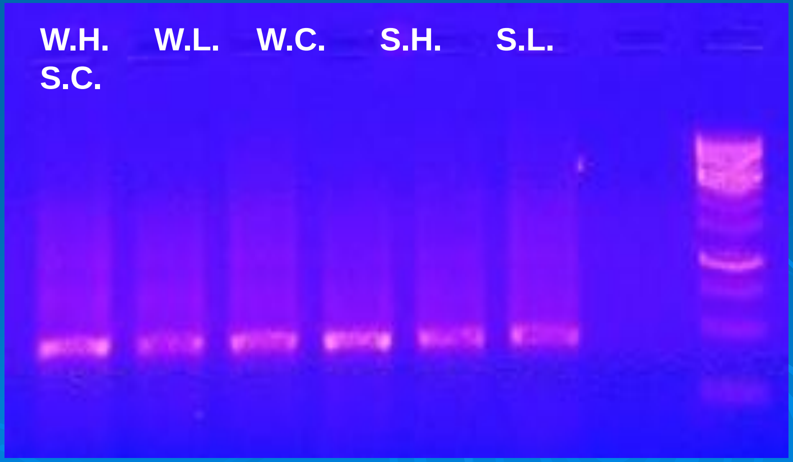


All Anammox (1484 bp)





Brocadia and/or kuenenia (452 bp)



Scalindua (452 bp)

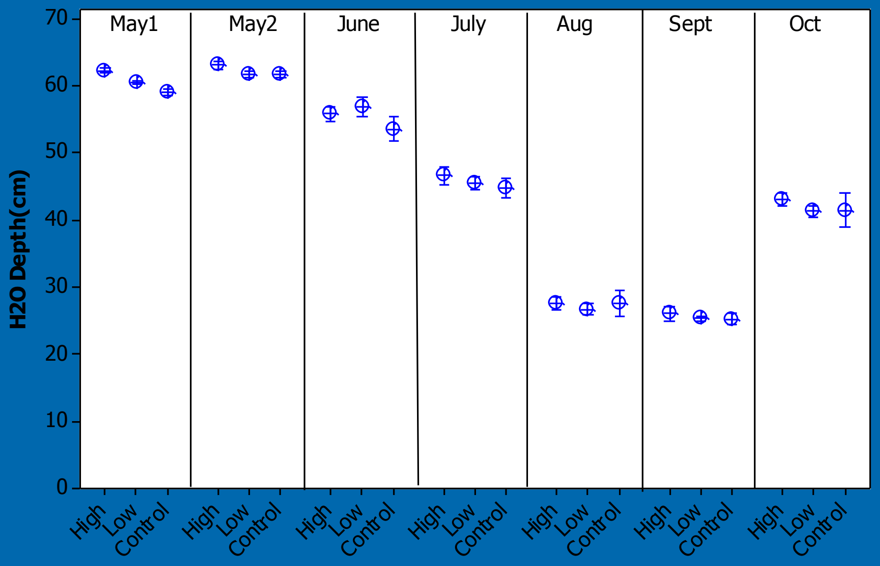
Discussion

- Willard Spur sediments and water column tend to be a sink for nutrients during the daylight hours (i.e., photosynthesis may be masking ammonia and phosphorus fluxes from the sediments by direct bioassimilation).

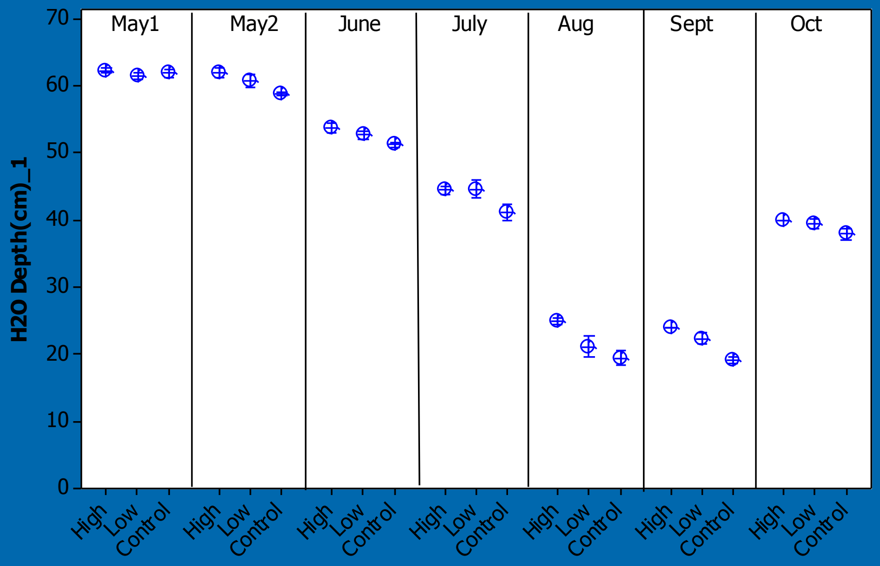
Vegetative Response

Results

H_2O Depth



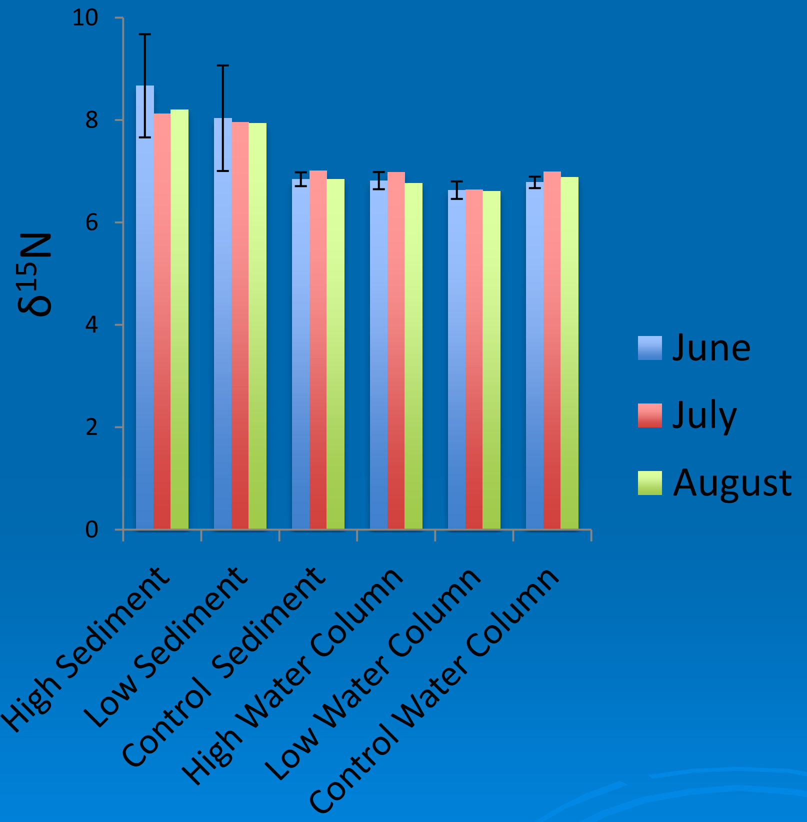
Water Column



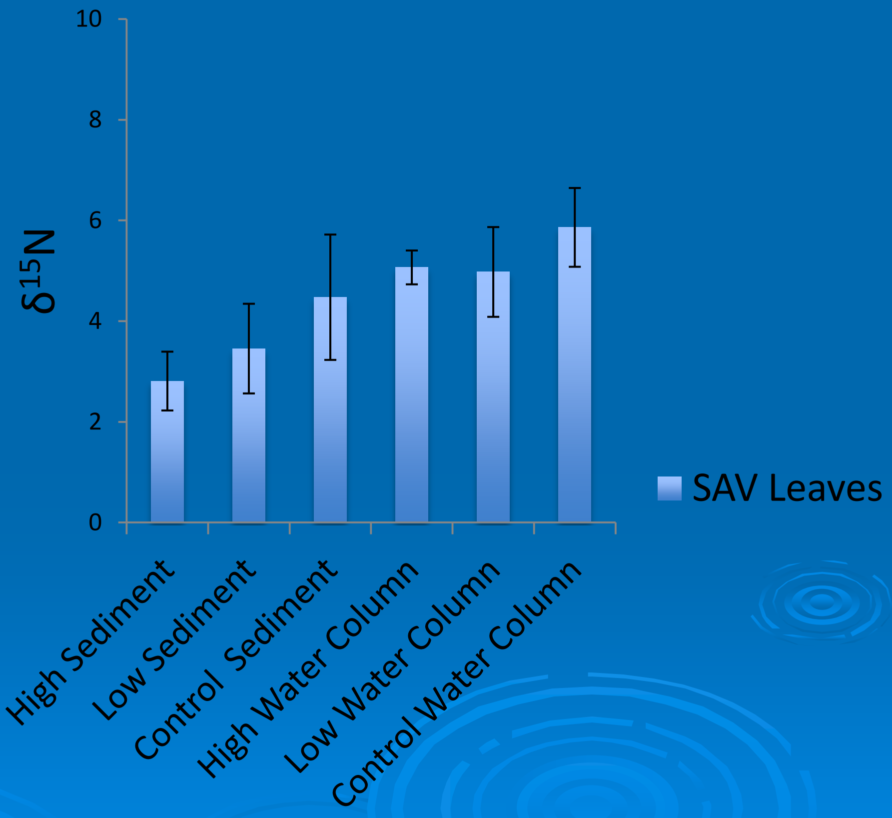
Sediment

Sediment and Plant $\delta^{15}N$ Isotope Values

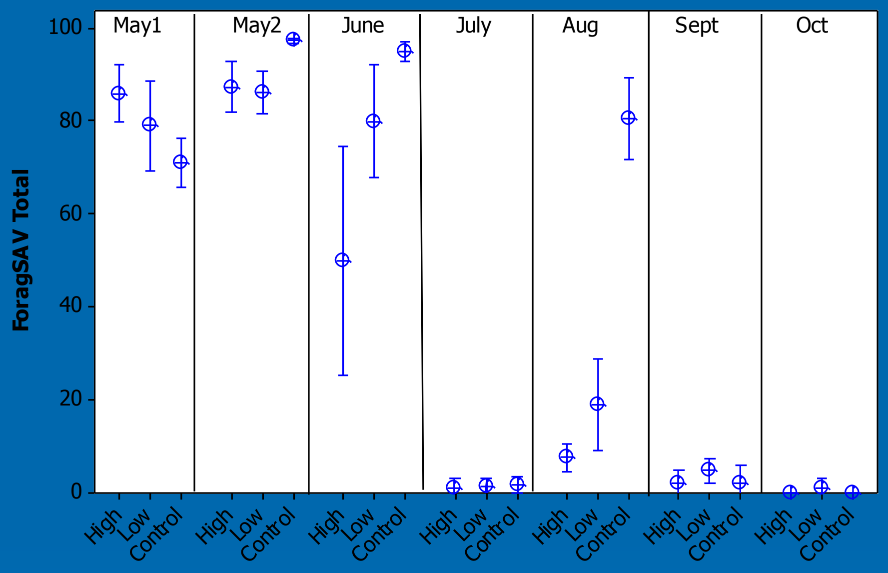
Sediment: Total $\delta^{15}N$



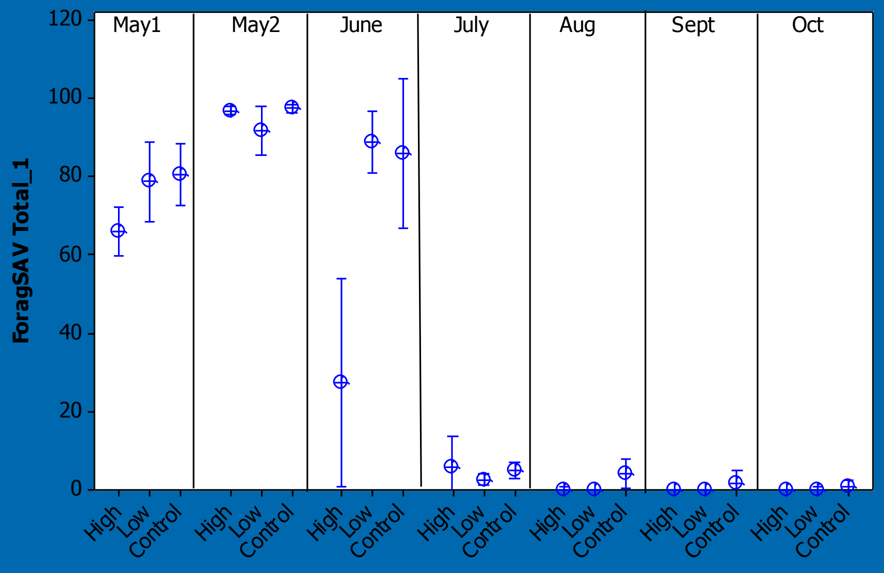
Plant Leaves: Total $\delta^{15}N$



Forageable SAV

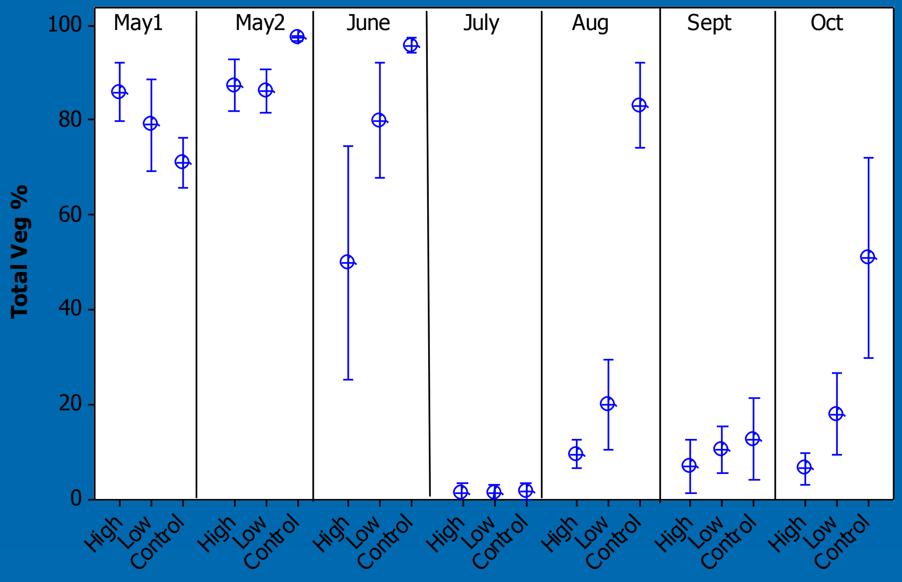


Water Column

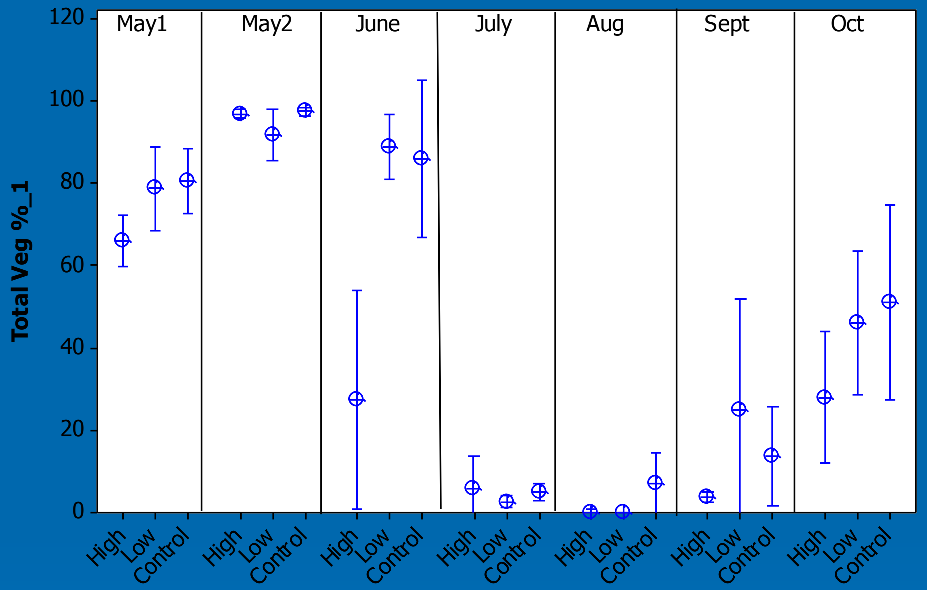


Sediment

Total SAV

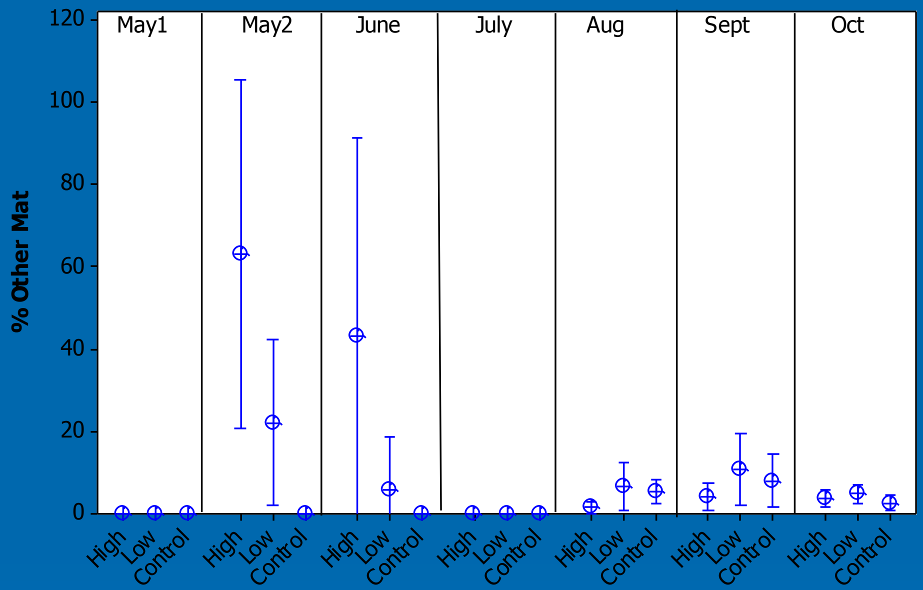


Water Column

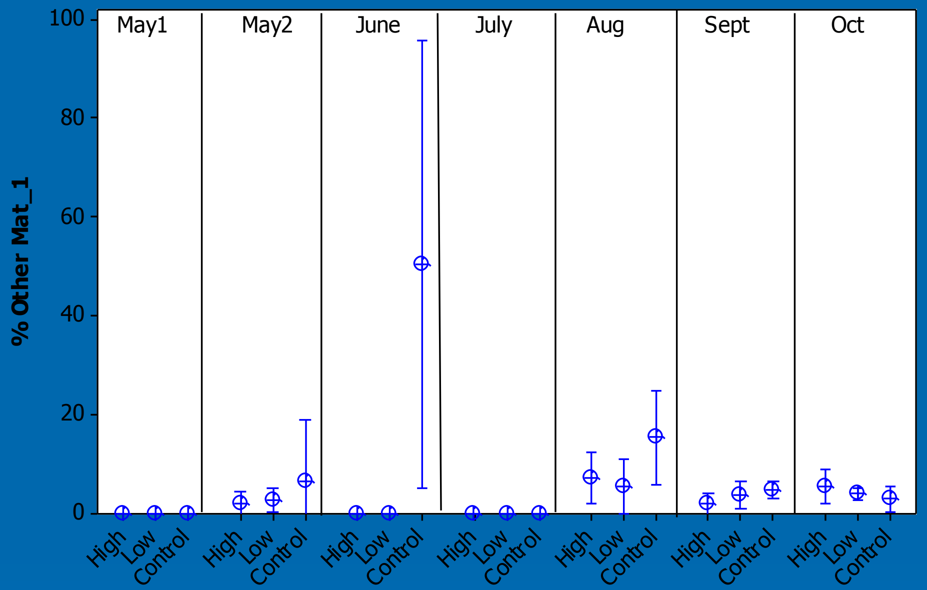


Sediment

Drift SAV

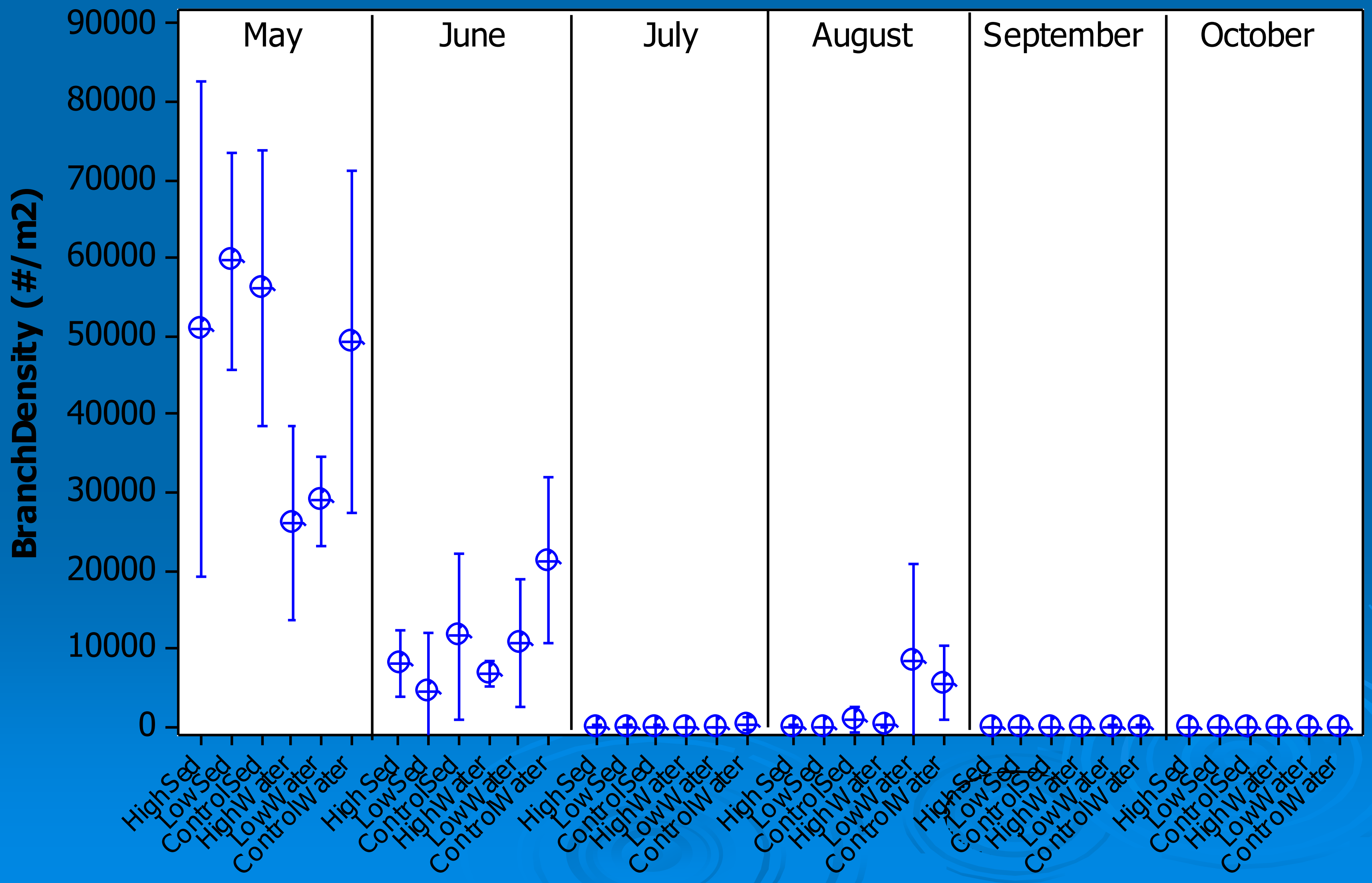


Water Column

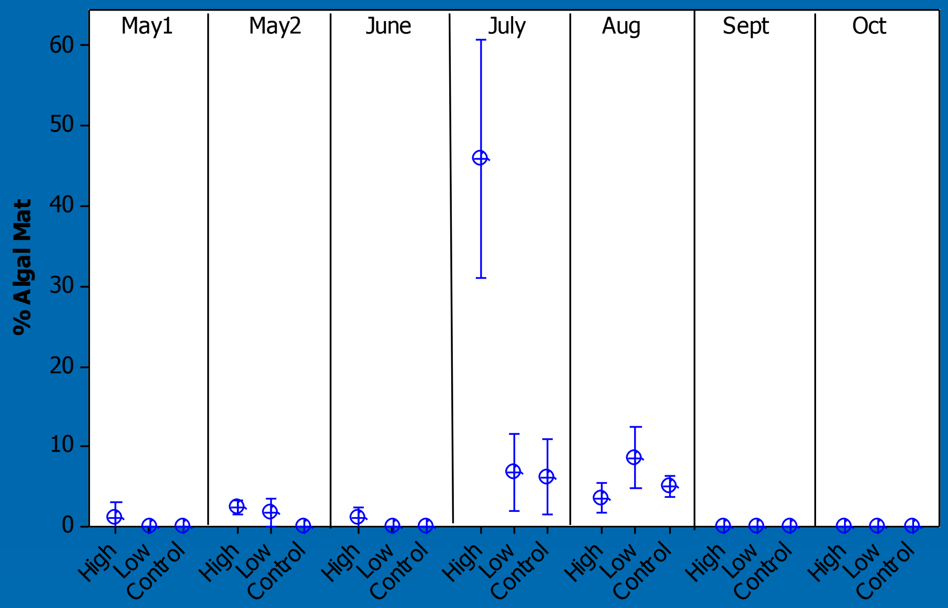


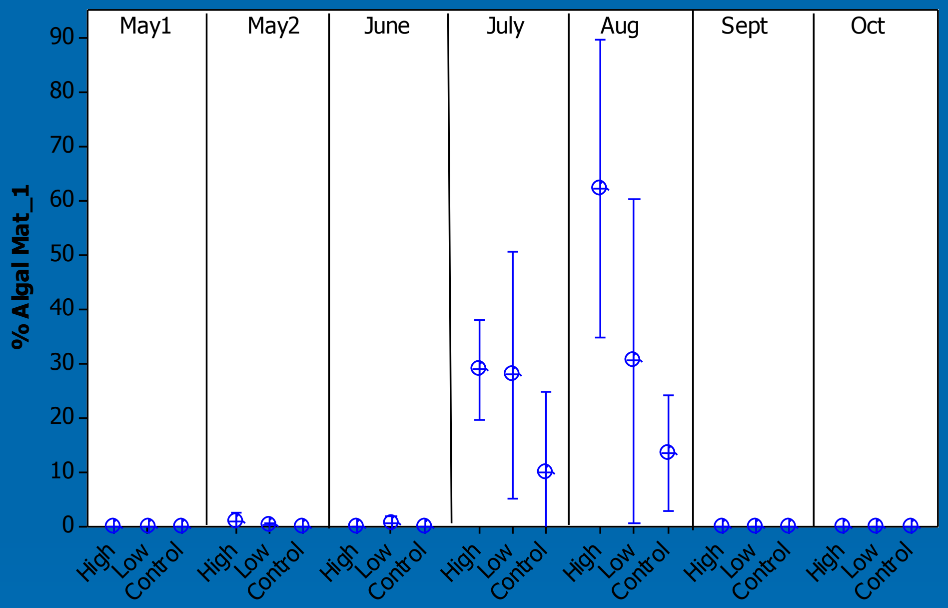
Sediment

Branch Density



Surface Algal Mat

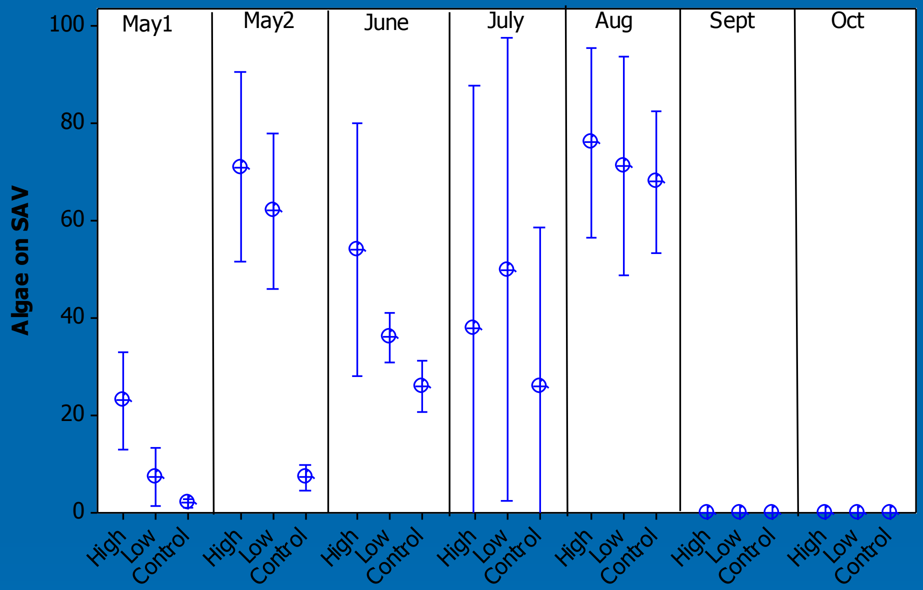




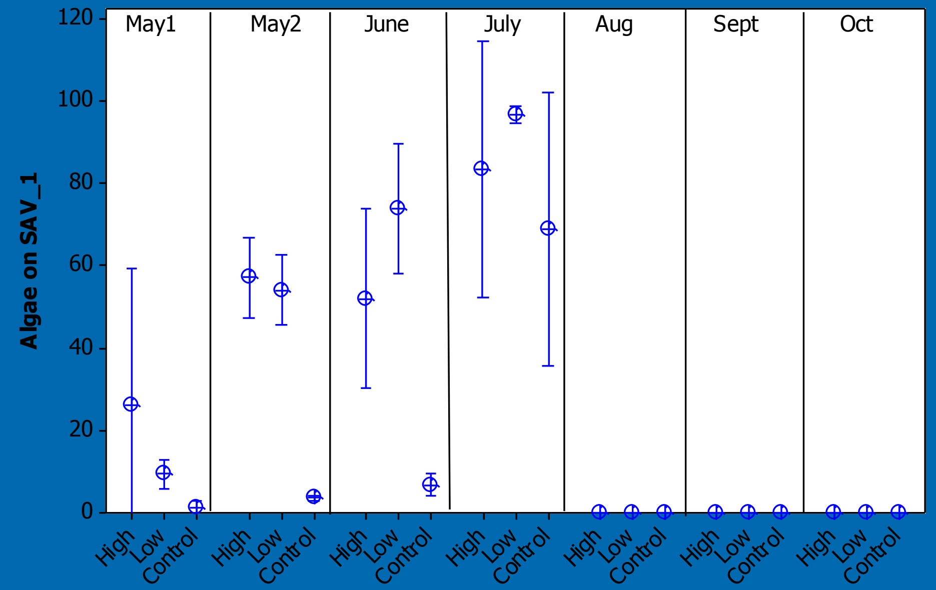
Water Column

Sediment

Epiphytes

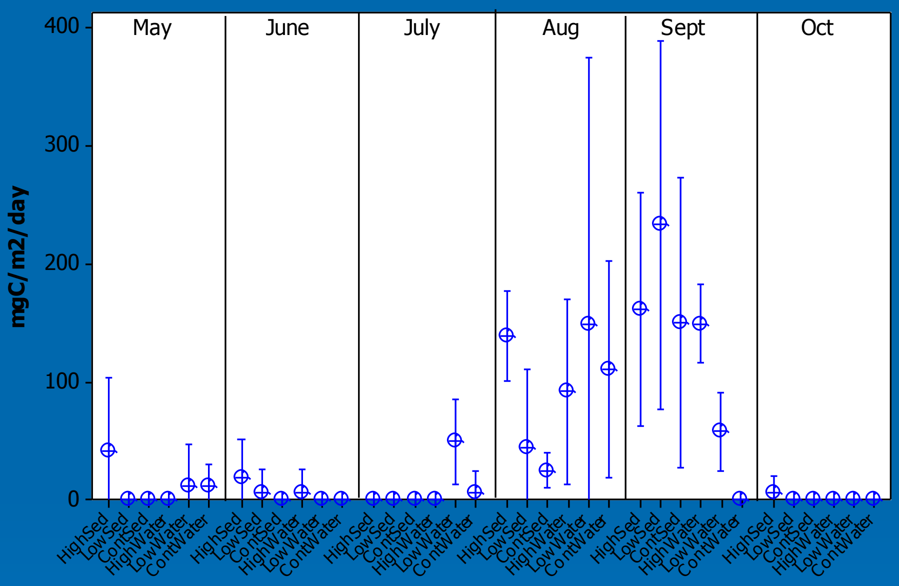


Water Column

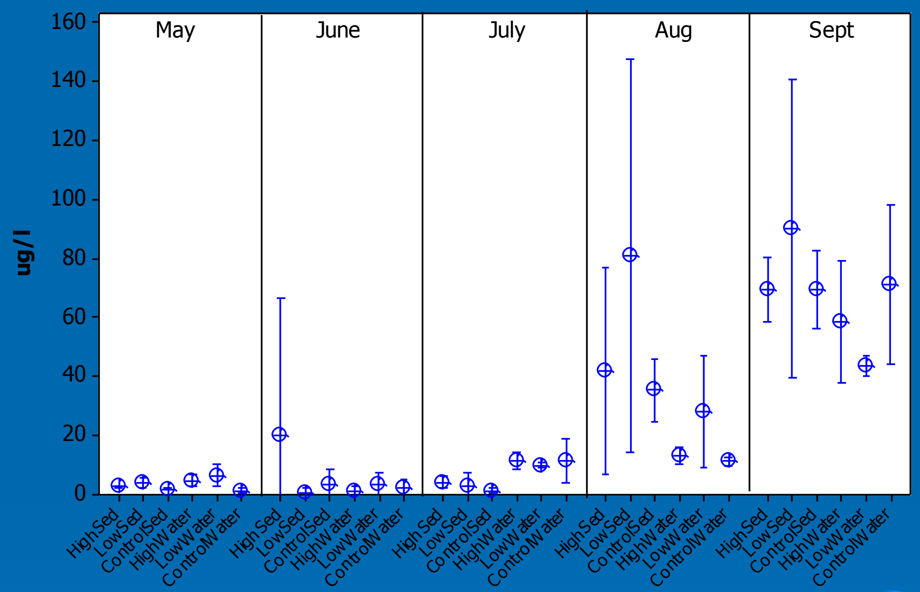


Sediment

Macroalgal Productivity & Chl *a*

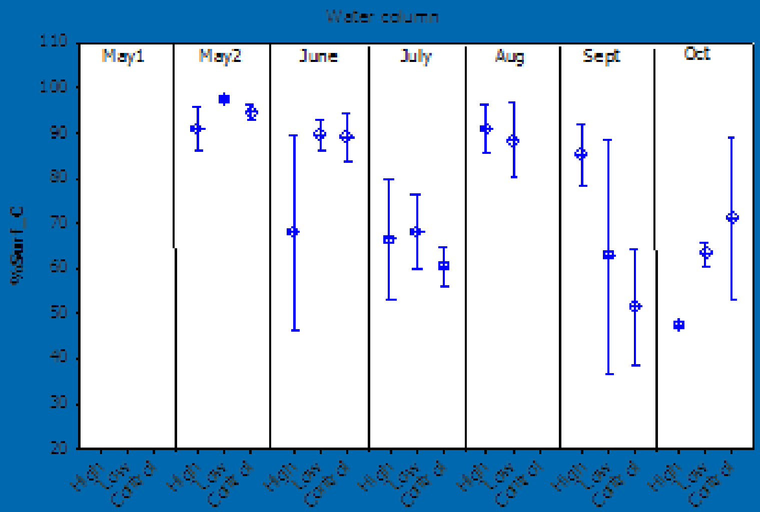


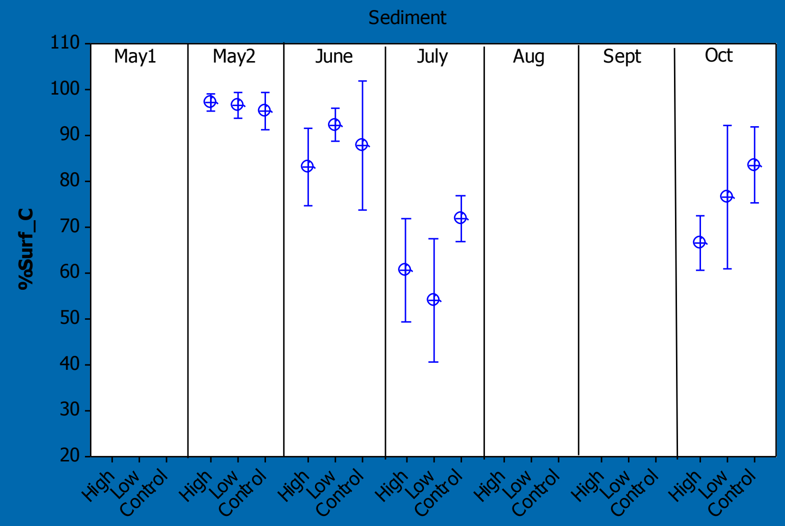
Macroalgae

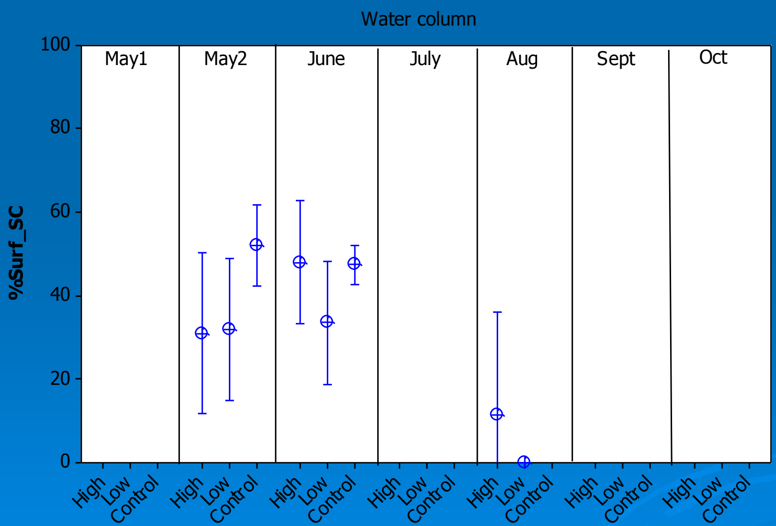


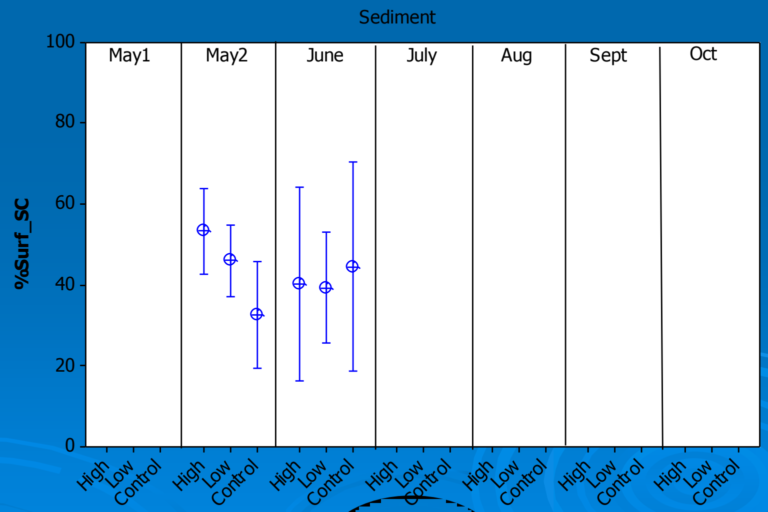
Chl *a*

Light Penetration





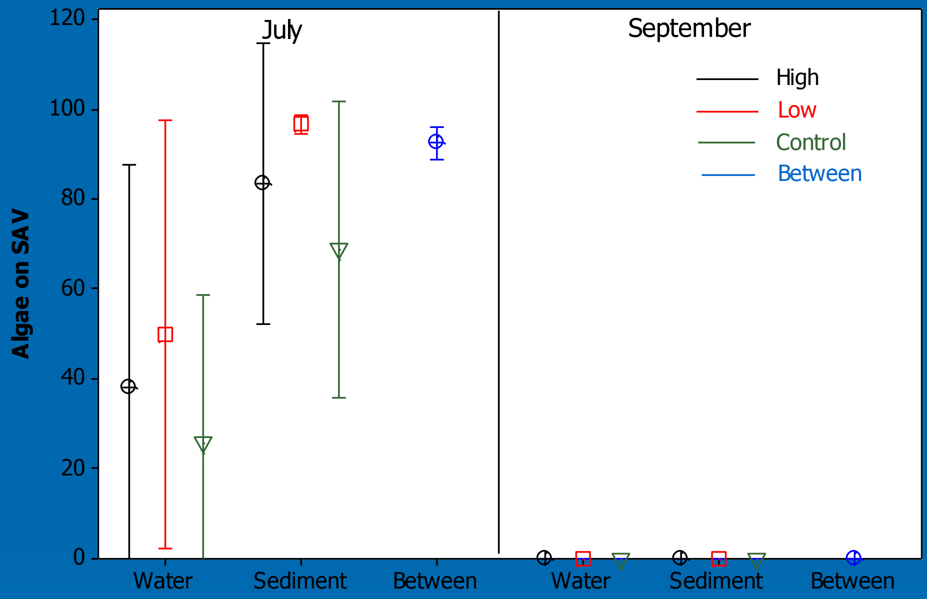




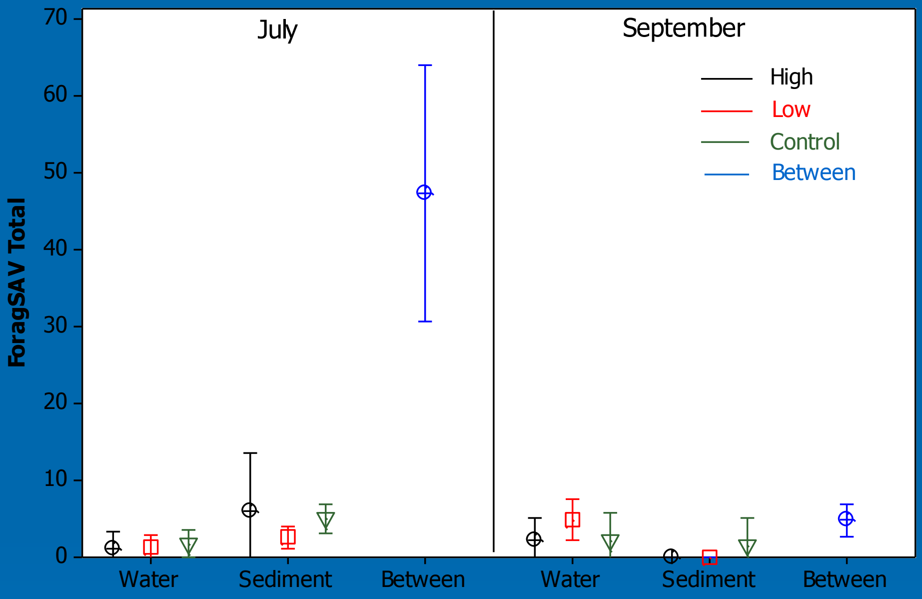
Water Column

Sediment

Between Plots Transect



Epiphytes



Forageable SAV

Discussion

- Significant depletion of $\delta^{15}N$ in SAV leaves in the sediment amendment plots.
- Stronger, lasting response by the **forageable SAV** in the sediment amendments. *
- Declining trend in **branch density** from May to June (both amendments). *
- No significant trend in biomass of tubers or drupelets**, however, sig. lower than local impounded wetlands**.
- Algal mat development occurred during June, consistent with other local impounded wetlands (Hoven et al. 2011) and was after SAV die-off.
- Early response by **epiphyte cover** on SAV during May (both amendments) *
- Chl *a* and macroalgal productivity only showed seasonal trends.
- No significant trends in BDS (biofilm, diatoms, and / or sediment) on SAV but could be important to monitor. +
- Light penetration was likely adequate in all amendments (above the projected light compensation point range, where net photosynthesis = zero) (as low as 2.7 % surface light for STFI, Hoven 2010). +

Discussion

- Comparison of ambient conditions between the experimental plots revealed that ambient conditions supported SAV growth through July when SAV in the experimental plots (including controls) had already died.
  - **Conditions in the experimental plots compromised support of SAV growth.**
  - ***Treatment effects were still detectable***.
- The 2012 data identified a critical window of biological response during a low precipitation (dry) year.
  - **Between late April and mid- to late June.**

Macroinvertebrate Assemblages

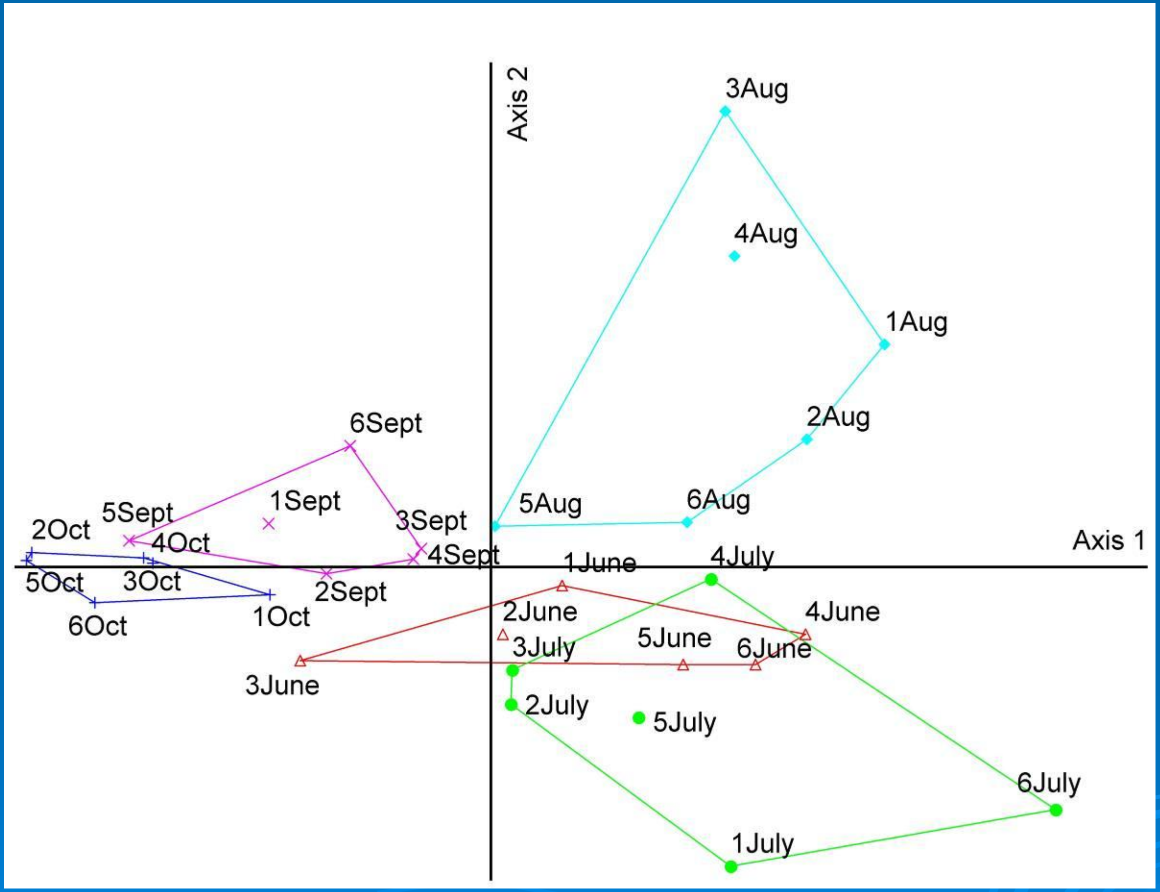
Results

15 taxa collected

	Family	Subfamily/genus/species	Functional Feeding Group
Ephemeroptera	Baetidae	*Callibaetis* sp.	Gatherer/collector
	Caenidae	*Caenis amica*	Gatherer/collector
Odonata	Coenagrionidae	*Ischnura* spp.	Predator
Hemiptera	Corixidae	*Corisella* spp.	Predator
	Corixidae	*Hesperocorixa* sp.	Predator
	Notonectidae	*Notonecta* sp.	Predator
Diptera	Chironomidae	*Chironomus* sp.	Gatherer/collector
	Chironomidae	subfamily Tanypodinae	Predator
	Chironomidae	subfamily Orthocladiinae	Gatherer/collector
Coleoptera	Hydrophilidae	*Enochrus* sp. (adult)	Gatherer/collector
	Chrysomelidae	(larvae)	Shredder
Acarina: Trombidiformes			Predator
Crustacea: Amphipoda	Hyalellidae	*Hyalella azteca*	Gatherer/collector
Mollusca: Gastropoda	Physidae	*Physella* (*Physa*) sp.	Scraper
Annelida (Oligochaeta)	Naididae		Gatherer/collector

Assemblages almost entirely determined by season

No treatment effect at the assemblage level



2-D NMS ordination
Final stress = 0.07

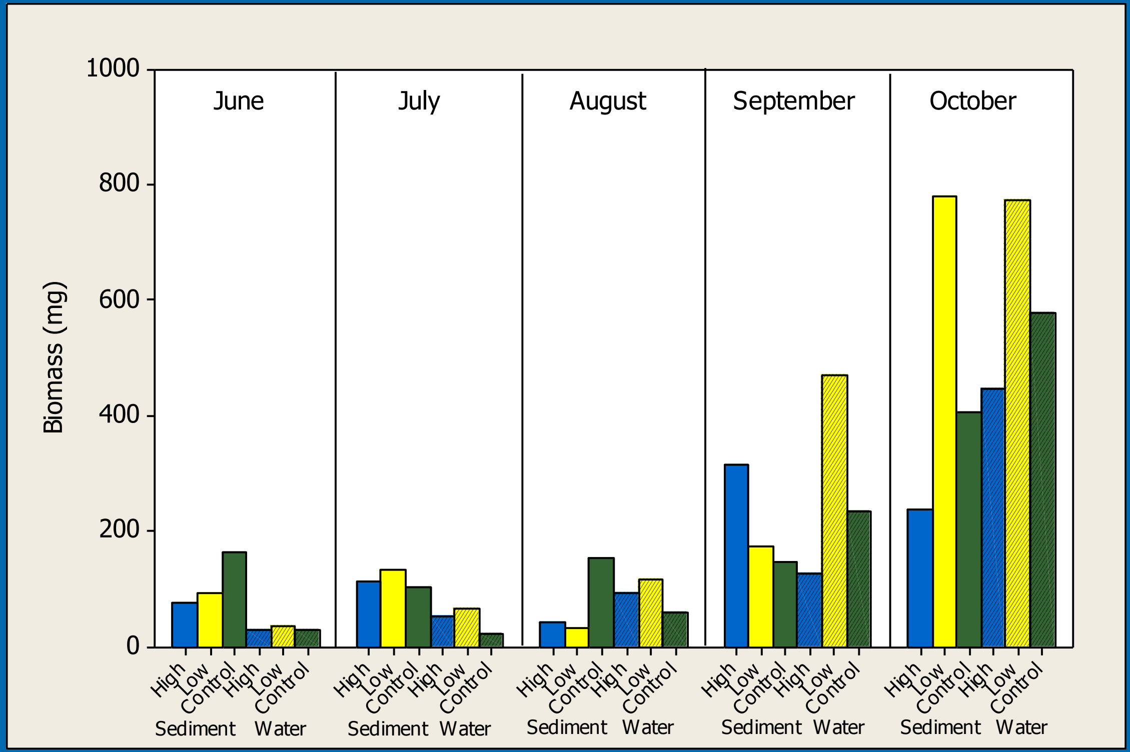
Mantel correlations on NMS axes

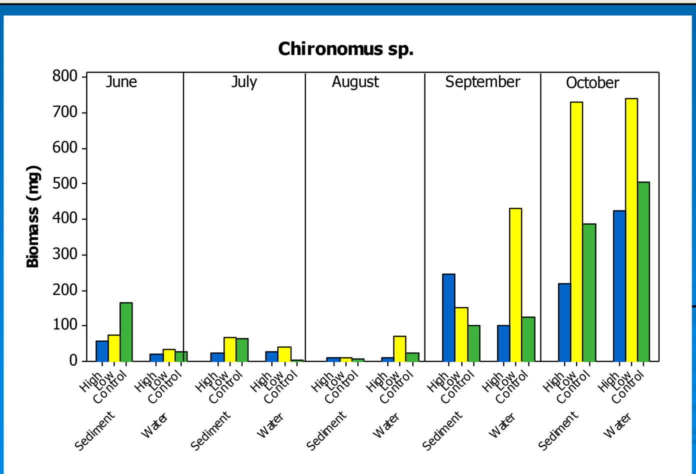
	Observed *Z*	Randomized *Z*	*r*	*p*-value
Month	0.105E+4	0.901E+03	0.41	**<0.01**
Treatment	0.109E+04	0.109E+04	0.01	0.45
SAV Metric				
% Algal Mat	0.846E+04	0.736E+04	0.21	**0.04**
% Other Mat	0.495E+04	0.494E+04	0.01	0.42
Total Mat	0.106E+05	0.976E+04	0.16	**0.08**
Algae on SAV	0.209E+05	0.194E+05	0.17	**0.02**
BDS on SAV	0.300E+05	0.248E+05	0.50	**< 0.01**
H_2O	0.786E+04	0.763E+04	0.07	0.11
Forage SAV	0.150E+05	0.160E+05	-0.09	0.19
Total Veg	0.174E+05	0.179E+05	-0.06	0.24
#STsp/m^2	0.222E+07	0.235E+07	-0.07	0.26

Assemblages and habitat

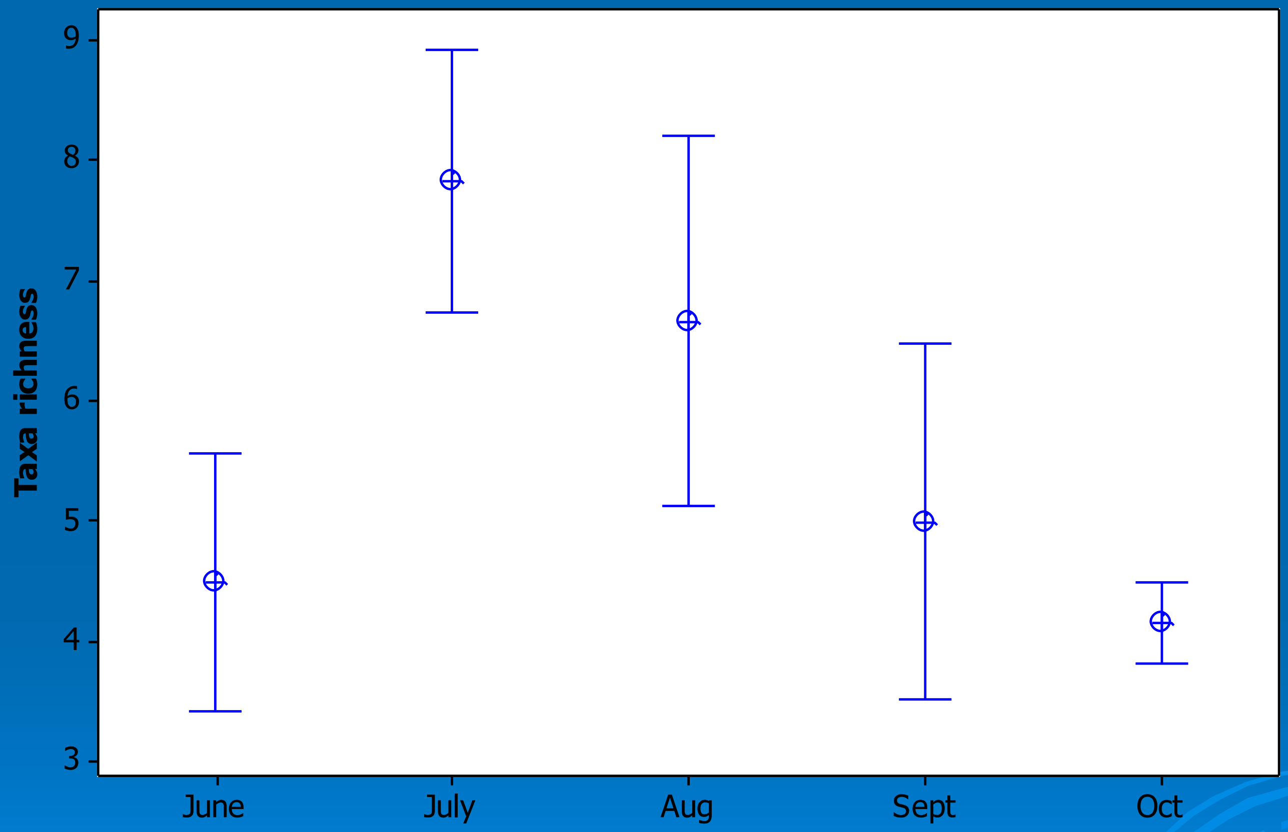
- Major switch in assemblages from that associated with submerged vegetation habitat in late spring/summer to assemblage associated with benthic habitat in autumn

Large increase in biomass Sept/Oct



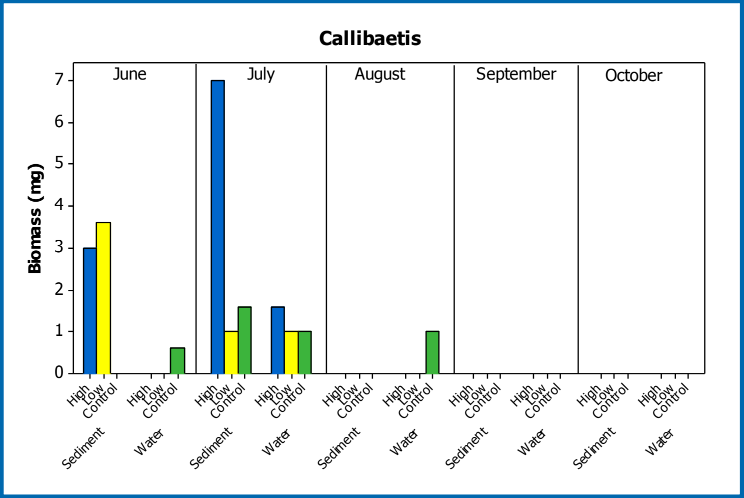


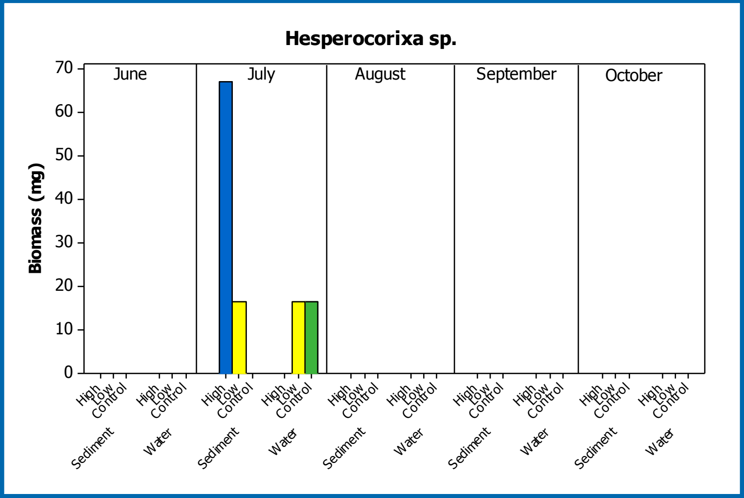
Taxa richness

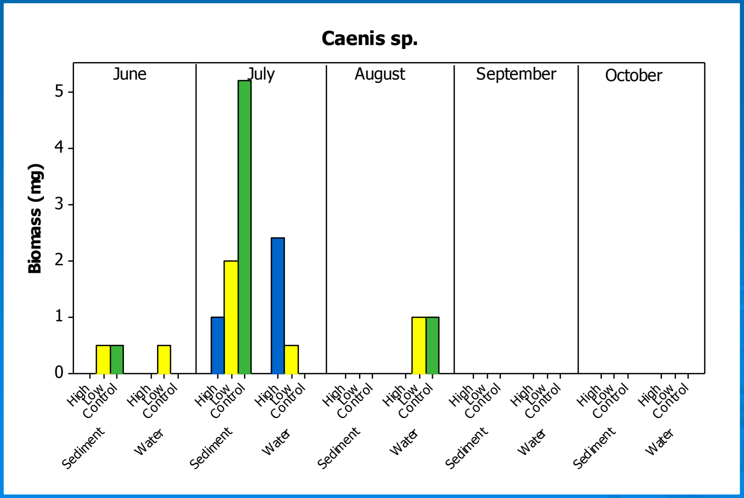


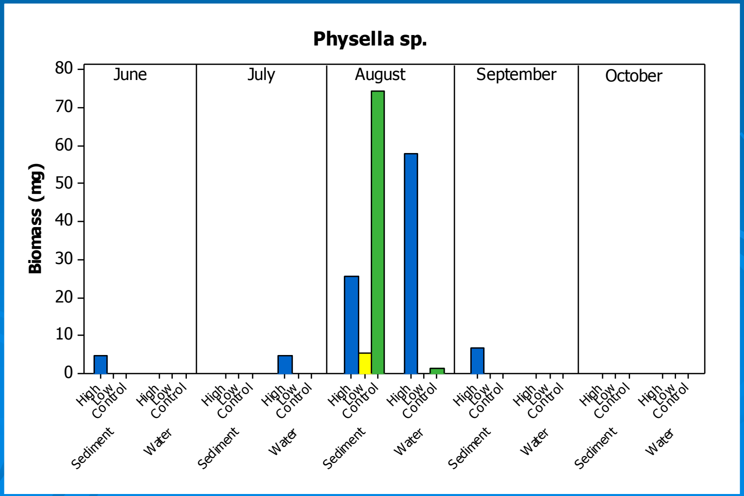
Many individual taxa showed seasonality as well

Examples



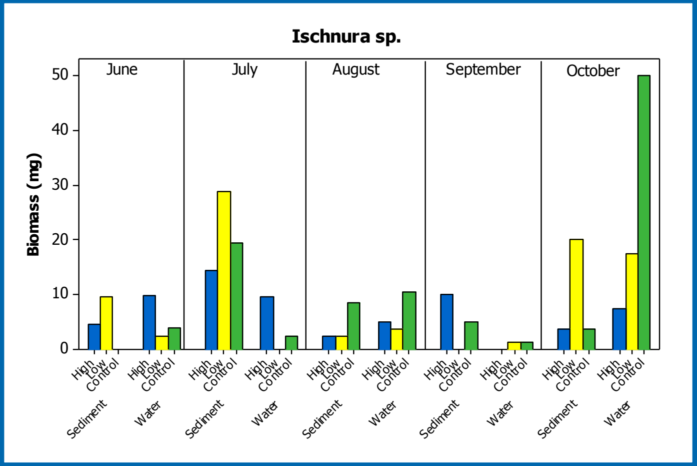


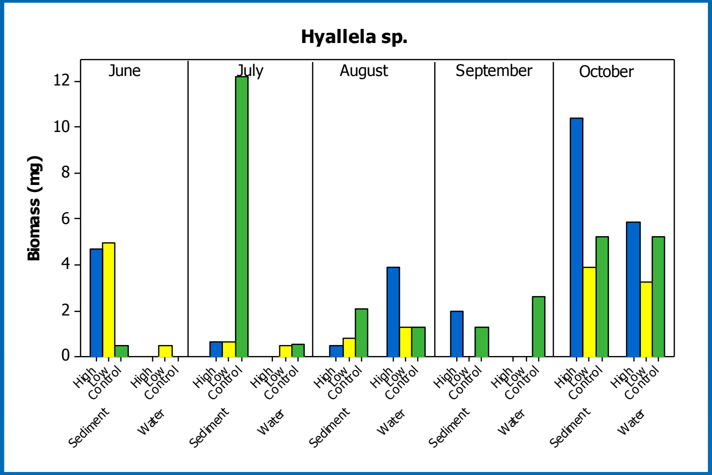


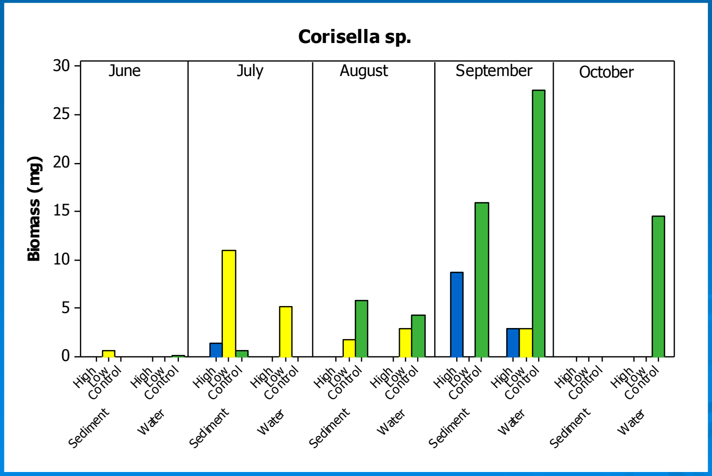


Some taxa occurred throughout season

Examples







More findings

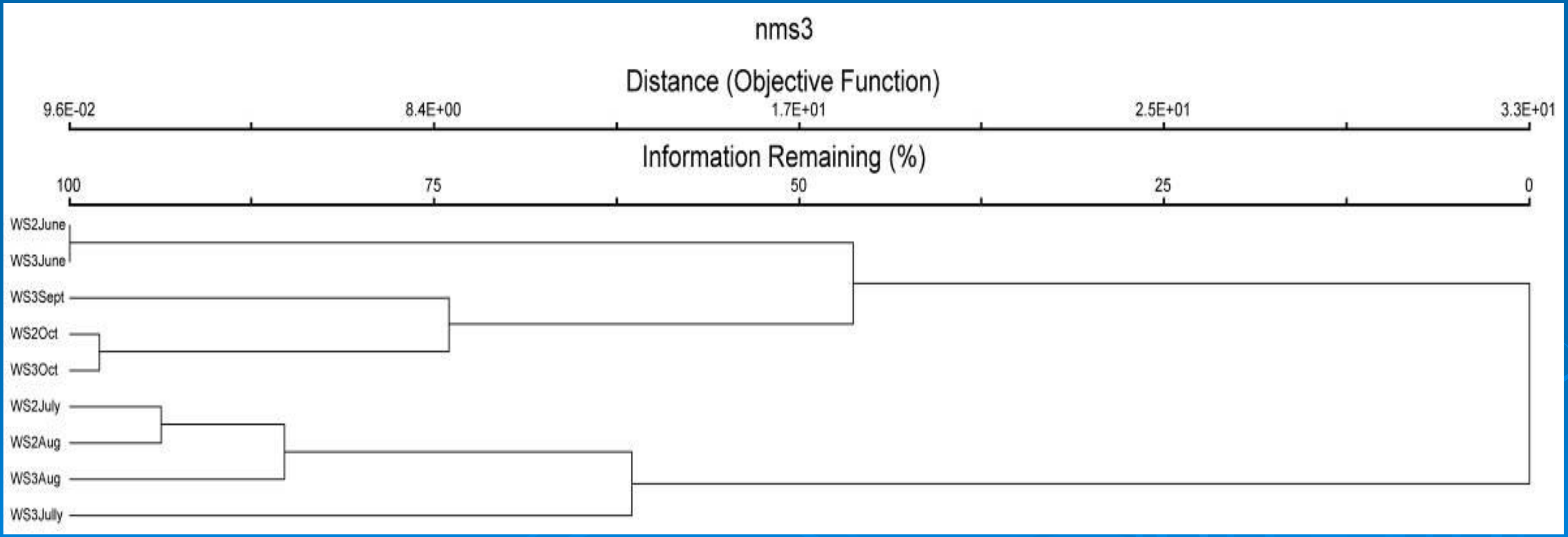
- No treatment affects on Functional Feeding Groups
  - Although seasonal increase of midges (Collector/gatherers) in autumn associated with shift in habitat type

Assemblages subset of WS assemblage and other SL wetlands assemblages

- Very similar to State of UT findings in WS (N = 19 taxa)
  - Oligochaetes collected in this study but not State of UT study

State of UT assemblage

- More determined by season than location in WS



Discussion

- Assessment of effects of nutrients must take seasonality into consideration
- Factors other than nutrients could be limiting including: temperature, light, flow, water chemistry, depth, habitat, etc.
- Many taxa were highly mobile and could have moved between treatments
- Life cycles of many of the taxa in this study were longer than the duration of the study

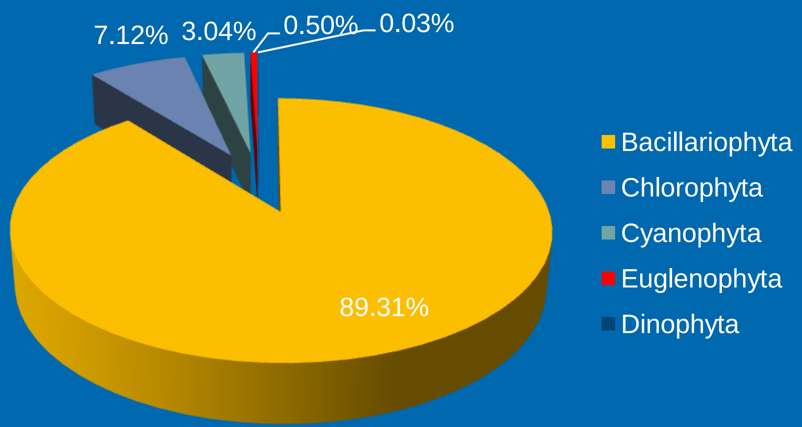
Discussion

- Scrapers and collector/gathers should respond more than other FFGs to nutrient enrichment

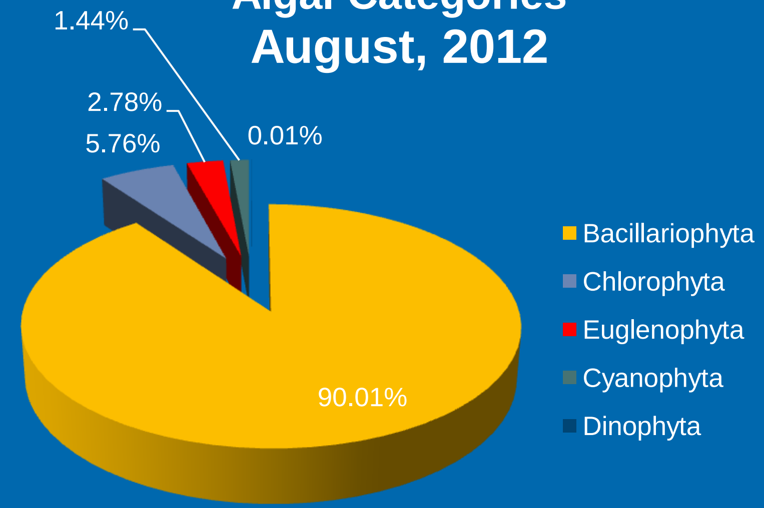
Phytoplankton Assemblages

Results

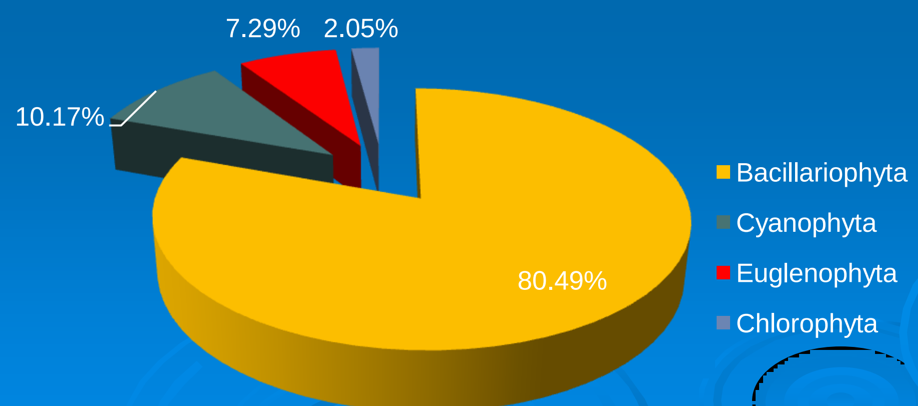
UUWS Phytoplankton Algal Categories July, 2012



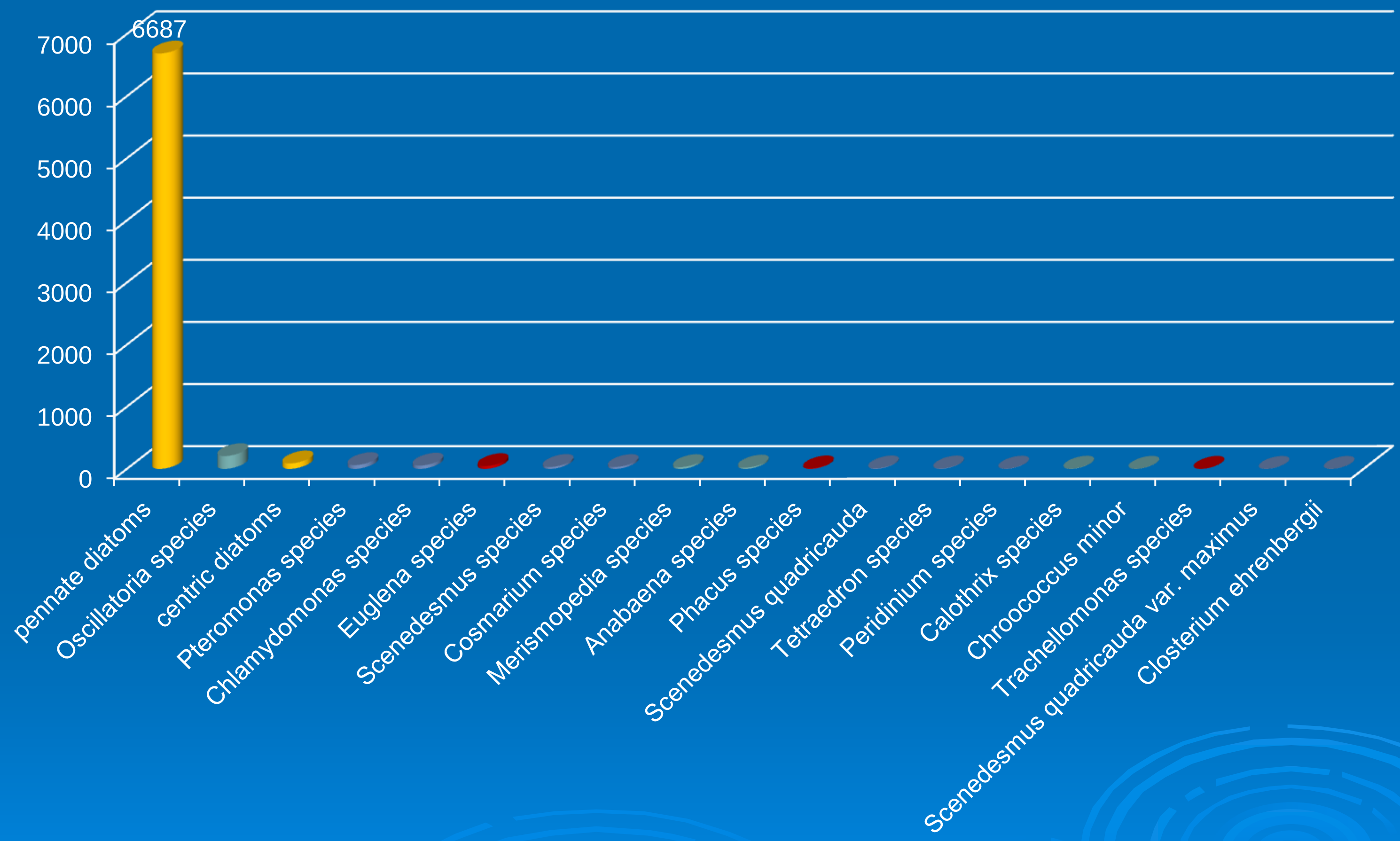
UUWS Phytoplankton Algal Categories August, 2012



UUWS Phytoplankton Algal Categories September, 2012

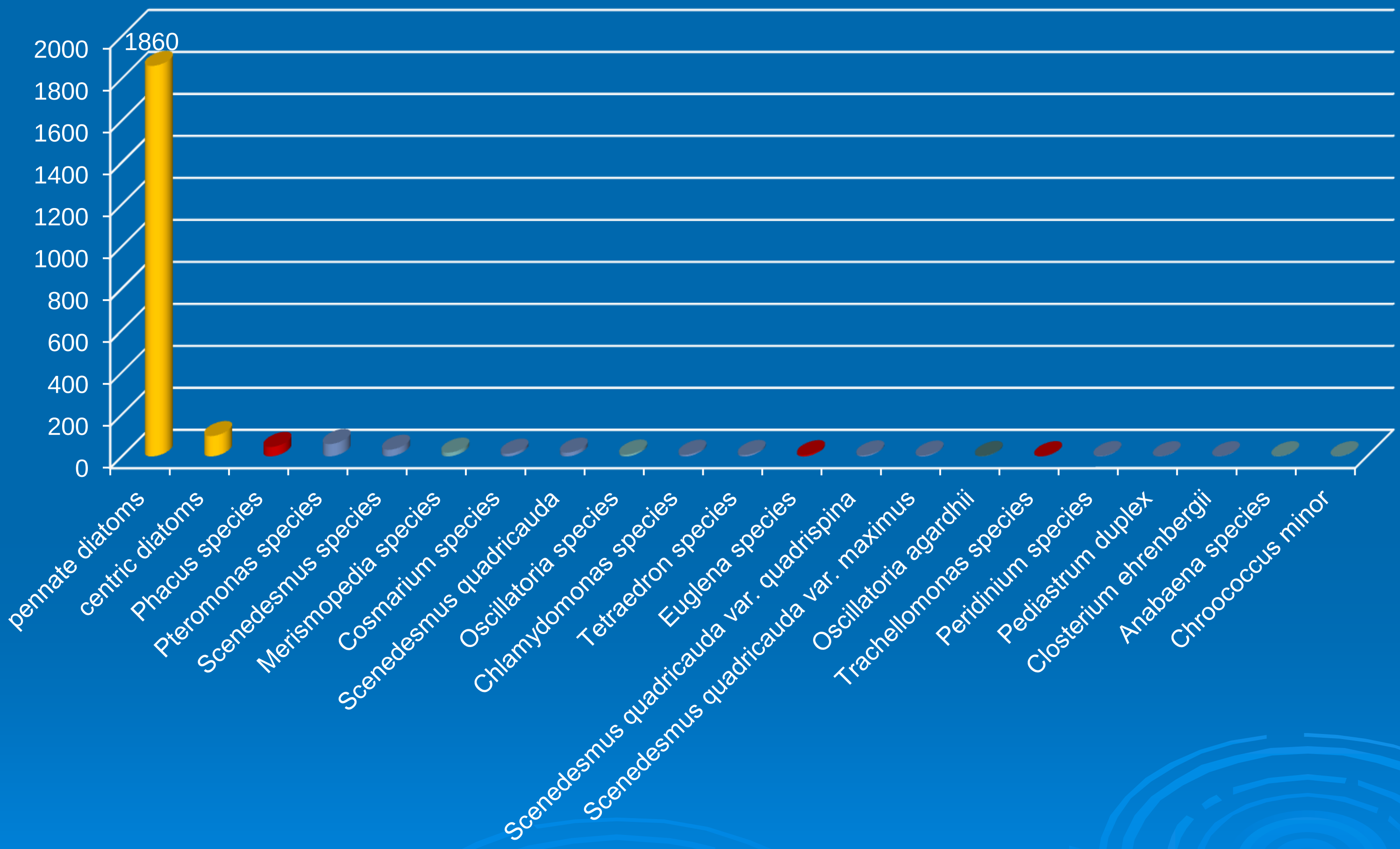


UUWS Phytoplankton
Species Count
July, 2012



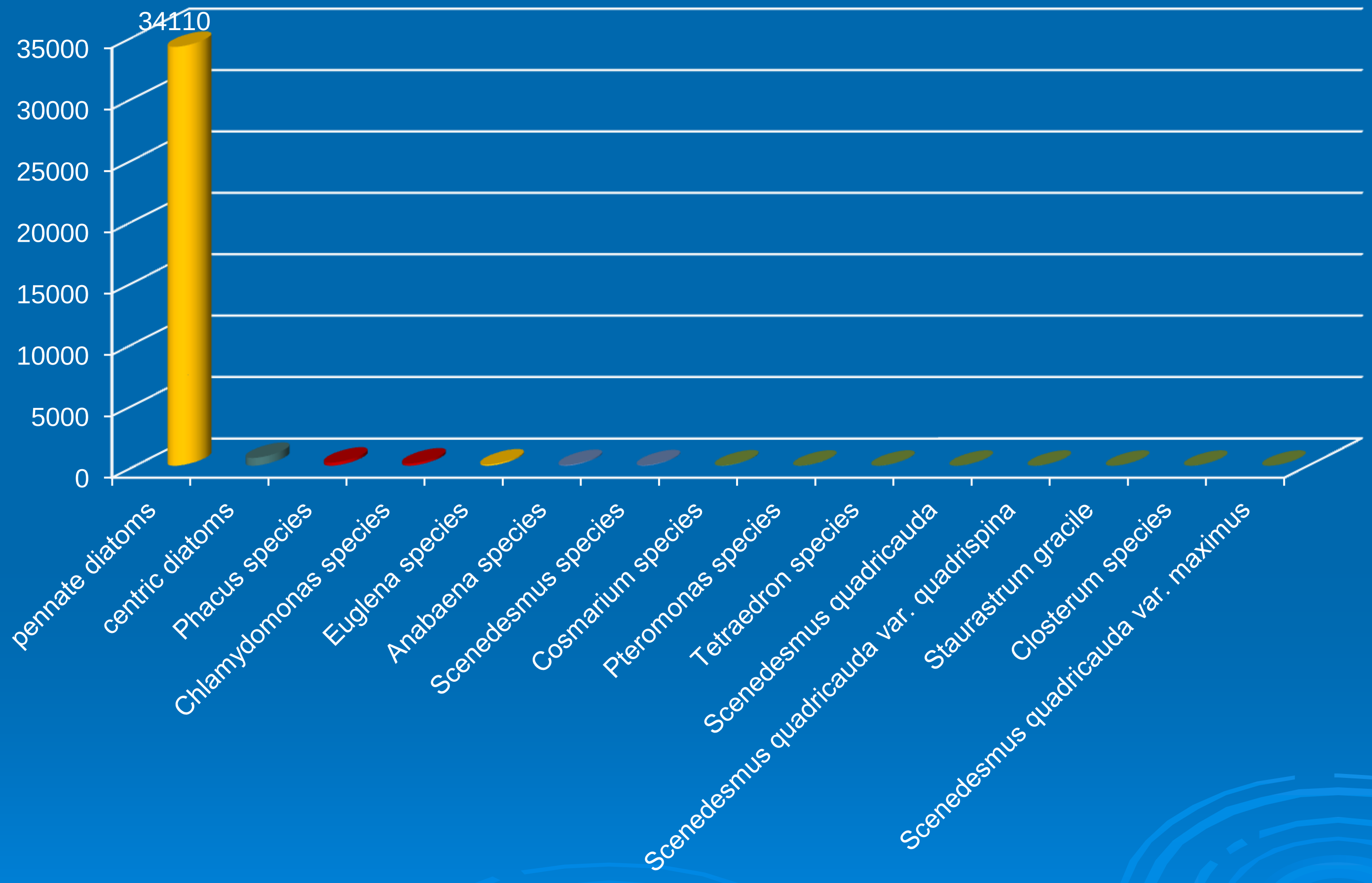
Number of Species: 19

UUWS Phytoplankton
Species Count
August, 2012



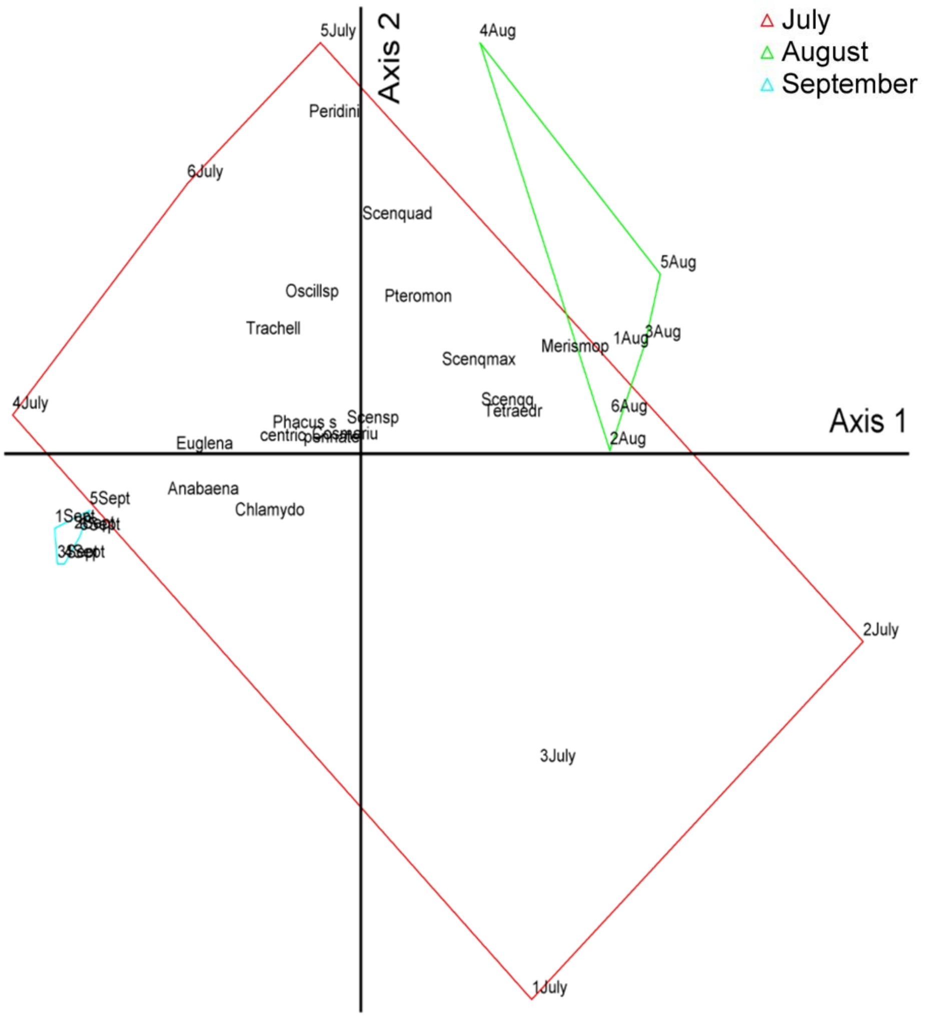
Number of Species: 21

UUWS Phytoplankton
Species Count
September, 2012



Number of Species: 15

NMS ordination



•Monthly separation was the most important

• Treatments were less obvious

(except for July where the sediment 1July, 2July, and 3July grouped very far apart from the water column July samples 4July, 5July, and 6July).

•September samples were extremely similar to each other; hence they were very close to one another.

UUWS Phytoplankton Treatments 1 -6

July – September 2012

	Anabaena species	***Calothrix*** species	Centric diatoms	***Chlamydomonas*** species	***Cosmarium*** species	***Euglena*** species	***Merismopedia*** species	***Oscillatoria*** species	pennate diatoms	***Phacus*** species	***Pteromonas*** species	***Scenedesmus quadricauda***	***Scenedesmus quadricauda*** var. ***maximus***	***Scenedesmus quadricauda*** var. ***quadrispina***	***Scenedesmus*** species
UUWS 1PH12 7/1/2012	1	0	3	26	2	0	1	0	52	0	1	0	0	0	3
UUWS 1PH12 8/28/2012	0	0	23	0	5	1	1	0	561	5	14	0	0	3	4
UUWS 1PH12 9/28/2012	14	0	151	25	5	2	0	0	2772	106	2	0	1	0	10
UUWS 2PH12 7/1/2012	0	0	1	0	3	1	2	0	224	0	0	0	0	0	4
UUWS 2PH12 8/28/2012	1	0	6	1	3	0	2	1	330	5	8	0	1	0	5
UUWS 2PH12 9/28/2012	4	0	91	57	7	13	0	0	2658	34	2	0	0	0	12
UUWS 3PH12 7/1/2012	7	0	0	8	3	0	5	3	115	2	0	0	0	0	4
UUWS 3PH12 8/28/2012	0	0	8	1	2	2	1	0	264	6	8	0	0	3	2
UUWS 3PH12 9/28/2012	15	0	118	44	6	44	0	0	5480	27	0	1	0	0	5
UUWS 4PH12 7/1/2012	2	0	2	0	5	34	0	180	4122	0	2	0	0	0	1
UUWS 4PH12 8/28/2012	0	0	45	4	1	0	6	5	331	9	23	12	0	0	9
UUWS 4PH12 9/28/2012	11	0	130	10	4	14	0	0	8284	16	0	0	0	0	6
UUWS 5PH12 7/1/2012	3	40	0	19	6	9	21	14	524	4	40	4	1	0	17
UUWS 5PH12 8/28/2012	0	0	6	0	2	0	2	1	231	11	5	3	0	0	7
UUWS 5PH12 9/28/2012	11	0	87	12	3	10	0	0	7491	26	4	4	0	0	4
UUWS 6PH12 7/1/2012	8	4	42	0	11	1	0	9	1650	3	18	0	0	0	6
UUWS 6PH12 8/28/2012	0	0	9	2	0	3	6	2	143	9	1	0	3	2	5
UUWS 6PH12 9/28/2012	9	0	62	34	1	23	0	0	7425	48	2	0	0	3	7

Mantel Tests

Variable	Observed *Z*	Randomized *Z*	*r*	*p*-value
Water Column				
Temperature	1167.20	1047.06	0.33	< 0.01
DO	972.77	948.68	0.08	0.16
pH	63.50	63.55	-0.01	0.52
SO4	1660.46	1516.42	0.31	<0.01
NO3-N	3.06	2.66	0.37	<0.01
PO4-P	3.82	3.31	0.31	0.02
Sediment				
Salinity	596.00	558.86	0.18	0.10
Phosphorus-P	6827.22	6607.06	0.07	0.26
pH	74.13	70.18	0.13	0.17
Nitrate-N	26724.10	25016.30	0.11	0.20
C:N ratio	148.89	136.80	0.27	0.01
Wt%-N	7.19	7.13	0.03	0.38
DeltaN15	161.08	161.86	-0.01	0.56

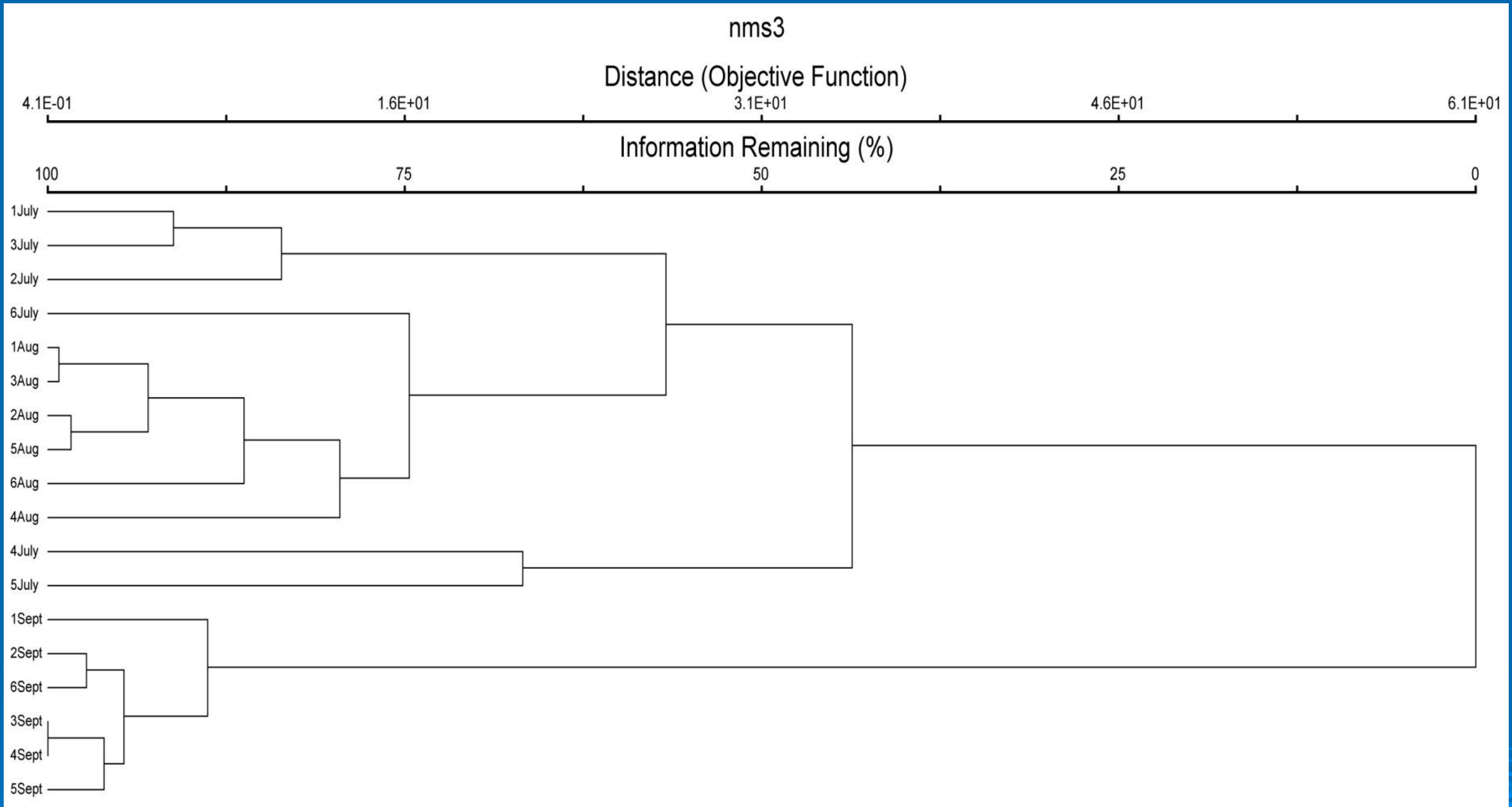
Correlation between Phytoplankton Assemblages and Metrics using Mantel Tests. (r = standardized Mantel test statistic; P-values are calculated from Observed Z vs. randomized Z test statistics). Correlations with p-values < 0.10 were considered important and are highlighted in yellow.

•Correlations between phytoplankton assemblages and relevant chemistry variables were conducted using Mantel tests on the NMS ordination axes on the July, August, September chemical variable data.

•Significant correlations (considered to be p-values of ≤ 0.10) were found between phytoplankton assemblages and:

•temperature,
•SO_4,
•NO_3-N
•PO_4-P
•Salinity
•C:N ratio

Cluster Analysis



•Cluster analysis showed similar relationships as the NMS solution (samples sorted mostly by month).

•Exceptions were 4July and 5July were more similar to August samples.

Recommendations

- Intensive focus on 1st half of season:
  - Focus on sediment amendments to better understand long-term deposition.
  - Initiate sample collection earlier to observe evolution of isotopic changes.
  - Modify % cover determinations to obtain species composition and cover during turbid months.
  - More frequent tissue CNP sampling to assess suppression of photosynthesis w/r/t C (Twilley et al. 1985).
  - Drop Chl *a*, and periphyton productivity.
  - Keep remaining plant metrics with a refined schedule.
  - Two different sources; e.g., ammonia present versus not.
- Physical changes to plots.
- Amendment refinement.

Recommendations

- Evaluate the contribution of aerobic nitrification and anaerobic ammonia oxidation in ammonia removal- very important.
- Deploying chambers overnight to measure “dark respiration” fluxes excluding primary production.
- Testing sediment cores in the laboratory to compare with chamber results (can measure light, dark, oxic and anoxic conditions for direct comparison).
- Spiking the chambers with known concentrations of nutrients to evaluate and measure the wetland capacity in nutrient uptake at target concentrations.
- Investigate sediment microbial community using microbiology techniques and lab-scale kinetic studies.

Recommendations

- Measure growth rates, fecundity, and size class differentiation of macroinvertebrates to determine short term effects of nutrient enrichment
- Continue analysis of phytoplankton assemblages.
- Identify planktonic diatoms to genus and species level in at least a subset of samples.
- Adding the identification of diatoms from one set of bottom sediment samples

DQO: Key Program Questions

- What are the natural, temporal changes that occur in Willard Spur submergent wetlands?
- What factors drive the changes?
- How do differences in nutrient conditions in the water column drive changes?
- How do differences in nutrient conditions in the sediment drive changes?

Site Set Up Budget

	Approximate Cost	Budget
Set Up Materials (Osmocote, posts, fence,…)	$6,800	$5,000
Sampling and Maintenance Materials	$3,100	
Travel	$1,600	$2,000
Total	$11,500	$7,000